PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

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THE LOOK BOX

THERE is a danger of concentrating disapproval on an individual rather than upon the conditions which permit an individual to harm the common good. Only recently the people of the United States were snarling at John L. Lewis, who was acting only within the bounds of a set of conditions whose correction is necessary to escape repetition of similar incidents. Without favorable soil, John L. Lewis could not have grown to his gigantic and distasteful statue, which at this writing has been somewhat self-reduced.

It's Not The Man

What comes out of the appeal of his conviction on contempt charges before the United States Supreme Court is not so important as the fact that such proposition could carry through to the extreme of the last court. When facing that, John L. Lewis backed down, as any man will, regardless of the arrogance with which he parades over common decency.

It is not enough to observe that John L. Lewis should not have the privilege of disrupting the economy of this country. No other man should have that privilege, no corporation should have it, no elected official should have it, and no one with the flavor of a dictator should have it. Unfortunately men have been encouraged in such acts. There has been appeasement in the relations of the national government toward labor. Often it was in the guise of carrying the war effort along.

Somewhere that had to halt or the nation would come to dictatorship. It looks like the halt has come.

But that is not victory, it is opportunity. The laws that encourage such action need revision or repeal. And that does not call for legislation against labor. We need no legislation against any group. We need legislation in fairness to all groups. When legislation bears that stamp it eliminates groups and that is to be desired above all else. Neither the men who call themselves labor nor the men who call themselves management should have the benefit of any laws behind which they can barricade themselves or upon which they can stand to shout. Groups and blocs are a sorry product of democrary.

It is to be hoped that the Congress forgets the labor group when it gets around to considering labor legislation. If bills are drawn with only the men of labor in mind and the determination to curb their activity, the result will be mean and trivial legislation. What the nation needs is not a law to prevent strikes or a law to compel men to go into arbitration in case of a strike. It should be the privilege of any man or any group of men to quit work as they please and to dicker over wages and hours when and if they please.

What they should not have is law and protective attitude when in quitting work they defy common decency by threatening other men who may want to take over. The closed shop as an agreement between men is a fine and healthy condition. As a club to be held over men who may not approve it, the closed shop becomes a privilege no man and no group should have.

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tion that any man can work or quit as he pleases and that no man and no group has the right to hamper that privilege, the soil which brought John L. Lewis to fruition will fail to support men of such arrogant disposition.

Certainly the Congress must provide legislation which will correct a situation where one man can control the entire national economy by opening or closing a faucet.

Aside from the economics of the situation, a sad situation arises when free Americans in as many thousands as submit themselves to the dictatorship of Lewis and his ilk, blindly and without question follow the orders of their overlords. Slavery is repugnant to our social setup whether the master gains his ascendency by purchase, coercion or persuasion.

Trend in Research

IN HIS remarks before the recent meeting of the Southern Research Institute Rubert P. Russell said:

"Standard Oil Development Company is now devoting nearly one third of all its research efforts toward the conversion of natural gas and coal into liquid fuels. However, this does not mean that the oil industry fears a future oil shortage."

After which he cited a recent statement by Eugene Holman, president of Standard Oil Company (New Jersey) to the effect that the industry expects this country to have as large proved oil reserves 20 years from now as it has today.

This is the attitude and the activity of only one organization in the petroleum industry, whose determination is to be ready for what may never happen.

Superior Qualities

FROM the exhaustive report of the United States Rubber Company, "Five Years of Synthetic Rubber," is this significant paragraph:

"The synthetic rubbers are preferable to natural rubber in applications totaling at least 100,000 tons per year. This estimate includes products which come in contact with oils and gasoline, pipe and tank linings for the chemical industries and products requiring unusual aging qualities. And it also assumes that most inner tubes will be made of butyl."

That chemical elastomer will be found to increase this requirement is an accepted prospect in technical circles. It would seem that technologists will through discovery solve the problem of maintaining sufficient plant capacity. Industry will demand enough of these superior products to make certain this nation always has a going synthetic-rubber industry, one that could be expanded to meet emergency needs.

Job for Industry

ONE of the encouraging concepts of this decade is the moulding of common opinion as to the true function of industry. Whatever its field, its true and final objective should be provision of more and better goods at lower prices. If it can accomplish that, the other minor objectives will abound.

Frequently industry is charged with the responsibility of making a profit, and it should. Frequently it is charged with the responsibility of providing adequate wages, which fortunately is gaining converts, since this is a worthy obligation. Industry can continue to do both, as well as the many minor obligations, if at all times it produces more and at a lower cost.

It was a comfort to witness presentation of an API award to the elder Henry Ford at the 1946 annual meeting, for the reason that Ford established a business on that principle, and the business has prospered. He looked upon the automobile as a machine which all men could own, whereas others considered it a machine fit for the few.

In finding means of so reducing the cost of this machine, Ford also found a way of increasing wages as well as profits. Henry Ford is not an outstanding man because he built a billion-dollar corporation. His value to mankind lies in the fact that in giving men a useful machine, a billion-dollar corporation came into existence.

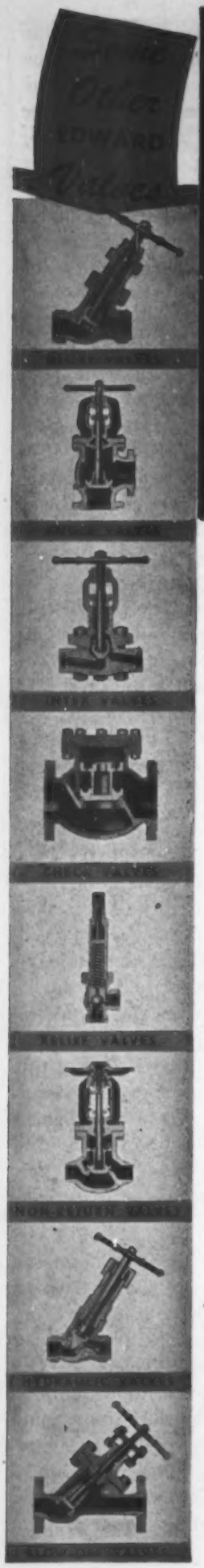
Despite Handicap

DESPITE the disruptions in steel making, somehow the refining division of the industry continues to register high in optimism. Announcements continue to get into print to the effect that old plants are going to be enlarged and modernized. Even some new installations come into the reports.

This is an industry bent on improvement. If the economy ever permits unrestricted purchasing, the skyline of the oil country is due for frequent piercing. Processing towers and stacks will tell the world that better motor fuel and lubricant as well as a host of useful chemicals are not only possible from oil and gas but actually in the making from these materials.

Colossal Optimism

FOR super optimism or unbridled recklessness nothing can surpass the presence of the oil experts of our State Department, who have gone to London to confer with proper men in England, just in case the Anglo-American Oil Agreement gets a favorable stamp in the Senate Foreign Relations committee. Perhaps the two just wanted a trip and having money appropriated for the purpose followed typical economy in Washington by making spending equal appropriation.



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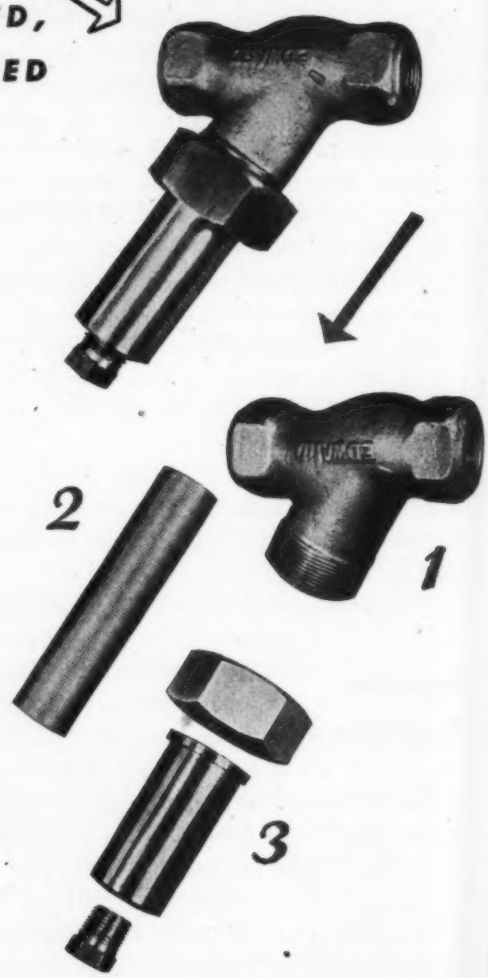

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Basic Oxygenated Chemicals From C-1, C-2 and C-3 Paraffins and Olefins

JOHN C. WALKER, Director of Chemical Research, and
HOWARD L. MALAKOFF, Chemical Research Division,
Cities Service Oil Company

DEVELOPMENT of the petrochemical industry has crystallized certain economic considerations which help to establish both its potentialities and limitations. It is well to review these economic factors to maintain a balanced perspective. There is no intention in enumerating these facts to depreciate in the least the value of the petrochemical industry. It has established its place in our economy and is destined, it is obvious, to grow by leaps and bounds.

Utilization of natural gas and petroleum oils for fuel and lubricant purposes will always be the principal end use. The total production of petroleum chemicals (aviation gasoline constituents and butadiene excluded) does not even now greatly exceed 1 percent of the total refinery output of fuels and lubricants, and the volume of natural gas converted to organic chemicals (carbon black excluded) is less than 1 percent of the total volume of gas consumed. Furthermore, it should be appreciated that the potential market for chemicals is not unlimited. Two simplified illustrations should substantiate this statement.

Formaldehyde is one of the large-volume products in the field of oxygenated hydrocarbons and organic chemicals in general. The United States Tariff Commission reports that the total production of standard commercial formaldehyde solution (37 percent HCHO by weight) during 1945 was 509,602,000 pounds (both from coal and natural-gas sources). A simple stoichiometric calculation will show, when theoretical conversion is assumed, that a single gas well producing somewhat under 7,000,000 cubic feet of methane daily would be sufficient to supply all raw materials required for this total production. Allowing liberally for nitrogen and other inerts to a total of 30 volume-percent, a well producing 10,000,000 cubic feet of natural gas daily would suffice. It is recognized that conversion does not attain theoretical expectancy by any known process, and that energy is needed in the manufacturing processes, with the result that substantially larger volumes of gas than theory requires are consumed in actual practice. Nevertheless, a single gas well producing 10,000,000 cubic feet per day is not an unusual phenomenon. This figure on an annual basis would be less than 0.1 volume-percent of the estimated 1944 marketed production of 3,828,500 millions cubic feet of natural gas.[5]

Oberfell[5] recites a similar example showing that if all the ethane and ethylene present in both the gases at refineries and raw natural gases during 1944 had been converted to ethyl alcohol, the production of ethyl alcohol would have amounted to about 8 times

PREVIOUS to the nineteen thirties, petroleum and natural gas had been thought of only as sources of fuels and lubricants. It has now been recognized that the trend towards use of petroleum and natural gas for the synthesis of commercial organic chemicals is the outstanding recent development in the chemical field. Today these raw materials are recognized as being veritable storehouses of valuable organic chemicals. We are no longer surprised at announcements of new products or of new processes for making familiar products from natural or refinery gases, better and more cheaply than by conventional methods from other raw materials. "Petrochemical," the word coined to describe this development is taking its place as common terminology alongside "coal-tar industry," "fermentation processes," and others.

Recent technical publications have presented review articles, covering developments in the petrochemical industry quite exhaustively.[1,2,3] It is not the authors' intent to present another digest of this extensive field, but rather to present a more intimate and detailed discussion of the chemistry and engineering of a phase of this development.

As indicated by the title of this paper, three important limitations have been selected to narrow down the scope of this discussion. First only oxygenated chemicals, such as alcohols, acids, anhydrides, aldehydes, ethers, ketones, and glycols will be discussed. Figure 1 gives the functional group of each of these type compounds, and the formula and name of one common member of each of these groups.

Only basic oxygenated chemicals are included. The authors arbitrarily define as basic, those chemicals which are produced in relatively large quantities and which are the primary or secondary oxygenated derivative from the starting hydrocarbon, rather than those that result from extended secondary syntheses. It is appreciated that the basic chemicals of today may not fulfill the above definition tomorrow in our fast moving chemical world. Figure 2 lists annual production figures for some of these chemicals. It should be noted that these figures include total production of synthetics from both petroleum and non-petroleum sources, and that 1945 figures are still a reflection of wartime requirements.

Raw materials have been limited to the C_1 to C_3 paraffins and olefins; they are methane, ethane, ethylene, propane, and propylene. This choice has been dictated by the fact that most of the presently established oxygenated chemicals syntheses start with these hydrocarbons. Because of their favored "synthesis position," that is their availability in high concentrations and purity without too many processing steps and at low economic value, they give promise of remaining as preferred raw material source. These hydrocarbons are readily available from natural gas, recycling plants, natural-gasoline plants, and refinery gases.

the total requirement estimated for 1944 and 40 times the ethyl alcohol produced in 1940.

The dollar value of an income from chemicals compared with fuels and lubricants will be considerably higher than the 1 percent volume ratio given above. From source information available it is difficult, if not impossible, to get even an approximate figure for this ratio. The following generalizations may, however, be safely made. Fuels are relatively low-value products with a steadily declining margin. Petrochemicals are on the average of higher unit value and are, as yet, farther away from the marginal profit zone.

Oxygenated Type Chemicals

Type Compound	Functional Group	Typical Compound	Formula
1. Alcohol	—OH	Methanol	CH_3OH
2. Acid	—COOH	Acetic Acid	CH_3COOH
3. Anhydride	$-C(=O)>O-C(=O)-$	Acetic Anhydride	$CH_3C(=O)>OCH_3C(=O)$
4. Aldehyde	$-C(=O)H$	Formaldehyde	HCHO
5. Ether	—C—O—C—	Ethyl Ether	$CH_3CH_2OCH_2CH_3$
6. Ketone	$-C(=O)-C-C-$	Acetone	CH_3COCH_3
7. Glycol	$-C(OH)-C(OH)-$	Ethylene Glycol	CH_2OH-CH_2OH

FIGURE 1

Organic Chemicals Production—1945[4]

CHEMICAL	Production, Lbs.	SALES Lbs.	SALES Unit Value $/Lb.
1. Acetaldehyde	.....	10,471,000	0.07
2. Acetic Acid-Synthetic (100...)	267,518,000	97,558,000	0.07
3. Acetic Anhydride-From all Sources	524,748,000	.....	...
4. Acetone:			
By Fermentation	42,417,000	42,498,000	0.07
From Isopropyl Alcohol	307,363,000	.....	....
5. Butyl Alcohol (n-Propylcarbinol) (100%)	129,364,000	.....	....
6. Ethyleneglycol	205,087,000	.....	....
7. Ethyl Ether, All Grades	76,598,000	.....	....
8. Formaldehyde (37% HCHO by Weight)	509,602,000	282,051,000	0.03
9. Isopropyl Alcohol	490,997,000	272,104,000	0.05
10. Methanol, Synthetic	493,110,000	344,911,000	0.03
11. Ethyl Alcohol, Undenatured (1943) (Wine Gallons—190 Proof)	272,000,000	.....	..

FIGURE 2

Coal Costs for Equivalent Btu Cost to Natural Gas

Gas Costs $/M	3	5	7
Coal Costs $/Ton	0.78	1.30	1.80

Coal Costs for Equivalent Pounds of Hydrogen and Carbon Cost to Natural Gas

Gas Costs $/M	3	5	7
Coal Costs $/Ton	1.05	1.75	2.45

FIGURE 3

Natural gas (dry) at present well-head prices is one of the cheapest sources of available carbon and hydrogen. Figure 3 shows the necessary coal prices for equivalent Btu value and pounds of carbon and hydrogen to natural gas.

Most other hydrocarbon raw materials are in a sense by-products of the petroleum, natural-gasoline, and recycling industries, and therefore their cost and value are difficult to determine. Since joint costs are involved in nearly every case, the cost of the by-product is likely to be influenced at least to some extent by the accounting procedure in use.

As long as their use for fuels determines the value of natural and refinery gases, these materials will, with little doubt, continue to be economically attractive as chemical raw materials.

Manufacture of chemicals calls for different type operations than petroleum-refinery and natural-gasoline-plant practices. It is characterized by higher investment costs per unit of production and higher unit operating costs. It involves the handling of smaller quantities, and the extensive use of corrosion-resistant materials of construction.

The petrochemical industry is very keenly competitive. Other than the patent literature there is very little published of other than very general interest. The higher degree of obsolescence necessitates shorter pay-out periods, and higher research budgets.

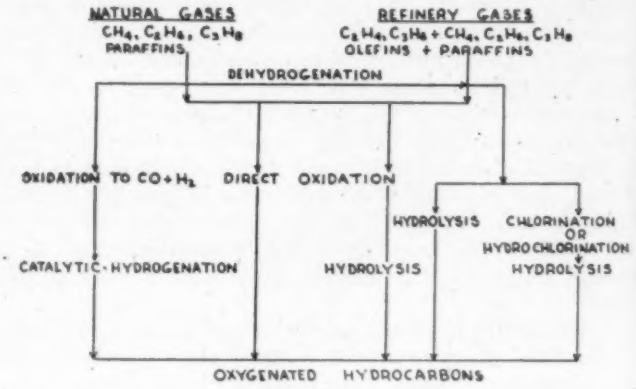


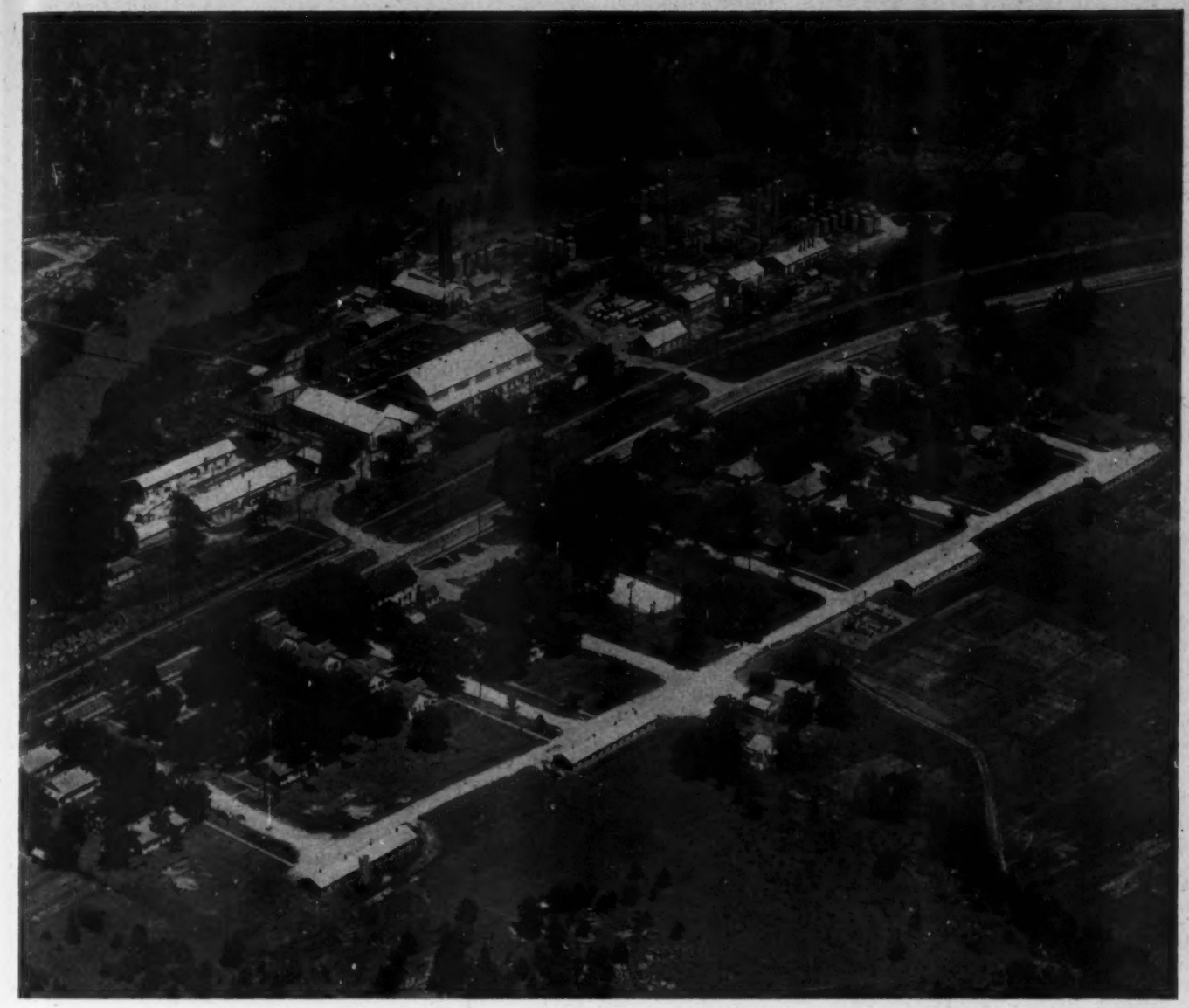
FIGURE 4
Oxidation mechanisms.

In the production of chemicals, the raw material "synthesis position" or its capacity to decrease the number of synthesis steps or manufacturing operations is an important economic factor. The lower paraffins and olefins, as has been pointed out, appear to hold a definite advantage in this respect.

The major source of natural gas and petroleum is in the Southwest. The large consumer markets are in the East and West. Location of the petrochemical plants near the raw material sources may in the future day of lower-cost chemicals and narrower profit margins, make freight costs a relatively important economic factor in competition with other processes situated closer to the point of consumption.

It is not intended to make this discussion an economic study of chemicals production from petroleum and natural gas versus chemicals from conventional processes. The previous comments have been offered only to suggest some of the problems which need be considered in the commercial development of the various chemicals which have been, and will be later, mentioned in this discussion.

To date, there have been four major approaches in the production of oxygenated hydrocarbons. They are, as is shown in Figure 4, (1) direct oxidation, (2) dehydrogenation followed by oxidation or hydra-



Tallant Plant of Cities Service Oil Company

tion, (3) oxidation to carbon monoxide and hydrogen followed by hydrogenation of the carbon monoxide, and (4) chlorination followed by hydrolysis. Several products to be discussed are now commercially manufactured by two or more of these schemes, economically competing with each other. Most chemicals, however, are presently produced by only one of these methods.

Direct Oxidation

Cities Service Oil Company has been the pioneer in the direct oxidation of the lower paraffin hydrocarbons to valuable oxygenated chemicals. J. C. Walker, one of the authors of this paper, and his associates discovered in 1925 that the corrosion of pipe lines caused by gas containing free oxygen could be minimized by bringing the gas to the necessary temperature and pressure to permit the oxygen present to be completely used up by reacting with the hydrocarbons. The formation of liquid oxygenated chemicals accompanied this reaction. The first commercial plant using an oxidation process of this type was constructed at Tallant, Oklahoma, in 1926. This plant has been expanded and three additional oxidation plants have been built. A modern chemicals refinery has been erected at Tallant to produce commercial-specification products from the crude oxidation products.

Methane, ethane, propane, and butane are the principal raw materials for this process. A typical oxygenated crude liquid mixture will contain 35 percent methanol, 20 percent formaldehyde, and 5 percent acetaldehyde as principal products. Acetone and dimethyl acetal also are present in recoverable quantities. Water and higher alcohols are the principal impurities. The unit operations of fractionation, liquid-liquid extraction, vacuum distillation, filtration, adsorption, and ion-exchange are all involved in processing the original crude chemical mixture to finished marketable products. Heat transmission and fluid flow are of course involved also.

The Cities Service direct oxidation process has made some noteworthy contributions in the chemical field. To the unit process of oxidation it has helped to correct the erroneous impression still taught by some of our organic textbooks, as to the inertness and chemical stability of the paraffin hydrocarbons. In the field of unit operations, its refining process included the first commercial application of ion exchange other than in the field of water purification. To meet the rigid demands of the resin and plastics

Synthetic Methanol Reactions

$$CH_4 + H_2O = CO + 3H_2 \quad (1)$$
$$3CH_4 + CO_2 + 2H_2O = 4CO + 8H_2 \quad (2)$$
$$CO + 2H_2 = CH_3OH \quad (3)$$
$$CO_2 + 3H_2 = CH_3OH + H_2O \quad (4)$$

FIGURE 5

industries for low-acidity formaldehyde, an ion-exchange processing scheme was successfully employed.

A number of patents have been issued to J. C. Walker, covering the oxidation of the lower paraffin hydrocarbons.

More recently, Celanese Corporation of America has built a chemical plant near Bishop, Texas, to produce (by direct oxidation of hydrocarbons, reportedly propane and butane) methanol, acetone, acetic acid, formaldehyde and acetaldehyde. The research organizations of several oil companies are known to be investigating oxidation of the gaseous hydrocarbons.

Ethylene oxide, produced by the controlled catalytic oxidation of ethylene, is reported to be gradually displacing ethylene chlorohydrin as a raw material for synthesis of ethylene glycol and its derivatives. The Lefort U. S. Reissue 20, 370 patent,[6] which has been the subject of a recent court decision, claims good yields of ethylene oxide from the oxidation of ethylene, using a silver catalyst, activated with small amounts of gold, copper, or iron, and at temperatures of 300° to 700° F. Carbon and Carbide Chemicals Corporation has been a leader in this field.

Partial Oxidation to Carbon Monoxide and Hydrogen

From a historical viewpoint, industrially speaking, the partial oxidation of coal or coke to carbon monoxide and hydrogen, and the subsequent hydrogenation of carbon monoxide to methanol, is one of the earliest synthesis for the production of oxygenated chemicals. It has been, however, only in the last 10 years that natural gas has been used as the source for both carbon monoxide and hydrogen. Most of the government-owned methanol and ammonia plants built in the Southwest during the war have used natural gas as a raw material. It is perhaps surprising to note that despite the accumulated knowledge on the reaction of carbon monoxide and hydrogen throughout the past 25 years for the production of oxygenated chemicals, other than methanol, no other industrial syntheses have been developed. As will be discussed later, one appears in the offing.

A brief summary of the synthetic methanol process follows: Natural gas is reacted with steam in the so-called reforming process according to the reaction

$$CH_4 + H_2O = CO + 3H_2$$

However, since a 2-to-1 ratio of hydrogen to carbon monoxide is desired for the methanol synthesis, carbon dioxide is added to the reactants and the net reaction is:

$$3CH_4 + CO_2 + 2H_2O = 4CO + 8H_2$$

There are other ways of adjusting the H_2:CO ratio. The above reaction is highly exothermic and takes place at 750-900° C., requiring special alloy equipment, and is considered an expensive installation. Carbon monoxide and hydrogen are reacted according to the equation:

$$CO + 2H_2 = CH_3OH$$

This is one of the most important of the high-pressure syntheses in use today, a pressure of 4500 psi commonly being used. The catalyst most commonly employed is copper mixed with oxides of zinc, chromium, manganese, or aluminum. Temperatures employed are in the range of 300 to 350° C. Carbon dioxide and hydrogen may be used for the synthesis gas; however, in that case the methanol produced is diluted with water.

Methanol may be further oxidized to formaldehyde, and most of this country's production is obtained in this manner. The introduction of the synthetic methanol process in this country was undoubtedly the principal impetus to the development of the formaldehyde-phenol or Bakelite type plastics industry. Formaldehyde is an intermediate of great importance in the chemical industry as indicated by the end-use consumption figures[7] given in Figure 6.

DuPont, Heyden Chemical Company, and Commercial Solvents have been the principal producers of formaldehyde from methanol to date. Casein Corporation recently completed construction of a methanol conversion plant on the West Coast.

Dehydrogenation Followed by Oxidation and/or Hydration

Figure 7 is a graphical representation of the basic oxygenated chemicals produced by the above oxidative mechanisms. The largest volume of oxygen-chemicals are produced by these procedures.

The production of ethyl alcohol by the hydration mechanism indicated in Figure 7, is briefly summarized in a Chemical and Metallurgical Engineering flowsheet[7] describing the Standard Alcohol Company Baton Rouge plant which commenced operating in March, 1943. Ethylene from the adjacent Standard Oil Company of New Jersey refinery is "cleaned" and goes to an absorber where it is reacted upon by sulfuric acid with the formation of a mixture of monoethyl and diethyl sulphates. The liquid discharge stream or mixed esters are pumped to a hydrolyzer where they are decomposed into ethyl alcohol and diethyl ether. This mixture passes to a stripping still where the acid is separated from the vaporized mixture of alcohol, ether, and water. After any acid carry-over is removed in a scrubber, ether is removed by steam stripping. The final step in the process removes excess water by fractionation. The sulfuric acid used in absorbing the ethylene is recovered and concentrated for reuse.

Despite competition from established fermentation

Consumption of Formaldehyde
(Thousands of pounds, 37%)

USE	Amount	Percent
Total Consumption	485,292	100.0
Resins, Total	243,375	50.3
Phenolic	137,932	28.4
Urea and Melamine	101,048	21.0
Other Resins	4,385	0.9
Chemical, Total	199,409	41.0
Hexamethylenetetramine	64,407	13.3
Pentaerythritol	55,367	11.4
Rubber Chemicals	2,537	0.5
Other Chemicals	77,098	15.8
Other Uses	33,653	6.9
Textiles	7,998	1.7
Dyes and Intermediates	3,498	0.7
Leather	2,640	0.5
Embalming Fluid	1,148	0.2
Drugs and Pharmaceuticals	804	0.2
Miscellaneous Uses	15,392	3.2

FIGURE 6

processes, and war-developed "waste" processes, synthetic alcohol produced from the cracking of petroleum hydrocarbons is generally considered to be the lowest-production-cost ethyl alcohol. Alcohol from molasses, grains, potatoes, waste sulfite liquor, and wood wastes, the competitive processes, do not appear to have as healthy an economic future. Tousley in "The Economics of Industrial Alcohol"[8] states: "It is doubtful that the total cost of pure ethylene to synthetic alcohol producers is even now much in excess of 3 cents per pound (all costs included), and there are a number of people in the chemical industry who believe the postwar cost will be nearer 2 cents." With ethylene available at 2 cents per pound, the estimated maximum cost for synthetic alcohol is 10 cents per gallon.

Standard Alcohol Company's recently announced expansion of the Baton Rouge plant substantiates the economic trend. The annual production of ethyl alcohol in 1940 was 126 million wine gallons.[9]

Introduction of an ion-exchange process in the sugar-refining industry which appreciably reduces the amount of by-product sugar syrups or molasses is a factor of interest in the synthetic-alcohol industry. A recent announcement along this line was made by Chemical Process Company.[10]

In spite of the apparent competitive advantages of the ethylene method, it is undoubtedly true that the market will not be allowed to pass from the old-time "conventional" producers to this comparatively new competitor without a hard struggle. In addition, a variation of the Fischer-Tropsch synthesis which will be discussed later, is a potential competing hydrocarbon process to be reckoned with.

It is interesting to note in passing that acetaldehyde and acetic acid, the latter one of our large volume synthetics, are being produced commercially from ethanol by further oxidation steps. The market for acetaldehyde undoubtedly will expand with the increasing interest in pentaerythritol (a condensation product of formaldehyde and acetaldehyde) in the synthetic-resin field.

Referring again to Figure 7, it can be stated that the chemistry and engineering of preparing isopropyl alcohol from propylene follows closely the previously discussed production of ethyl alcohol from ethylene and so will not be further discussed here. Most of the country's isopropyl alcohol is converted into acetone by oxidative dehydrogenation. The United States Tariff Commission's 1945 production figures show 307,363,000 pounds of acetone produced from isopropyl alcohol, compared with 42,417,000 obtained by fermentation processes.

Acetic anhydride, the production of which from all sources was 524,748,000 pounds in 1945, is now being commercially produced through the thermal decomposition of acetone to ketene and reaction of ketene with acetic acid. The volume consumption of acetic anhydride is in the plastics and synthetic-fibre industries.

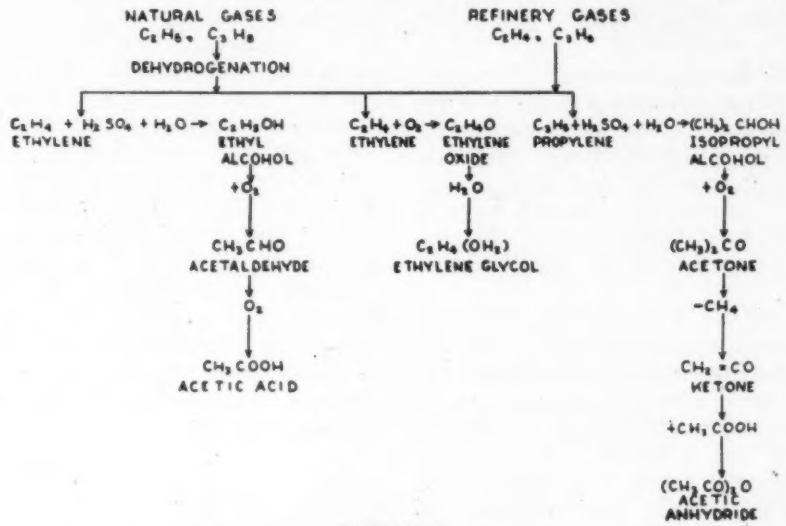


FIGURE 7
Dehydrogenation-hydration—oxygen compounds.

Production of ethylene oxide from ethylene was discussed with the direct-oxidation processes. Hydration of ethylene oxide yields ethylene glycol, the largest single outlet for which is the anti-freeze market; 205,087,000 pounds of ethylene glycol were produced in 1945 from all processes. Initial patent control of this process was held by Carbon and Carbide Chemicals Corporation but the recent court decision, previously referred to, and the termination of the basic patents will undoubtedly lead to opening up this field.

Clorination Followed by Hydrolysis

Production on an industrial scale of a basic oxygenated hydrocarbon through the chlorination route is a recent development. Shell Development Company in 1941 reported[12] the results of work initiated in 1936 on the production of synthetic glycerol from propylene. Production of allyl chloride by the chlorination of propylene, and the hydrolysis of allyl chloride to allyl alcohol were intermediate steps in this synthesis. As yet no synthetic glycerol plant has been built, but Shell Chemical Company recently completed a plant for the production of allyl chloride and allyl alcohol at Houston. Additions to this plant have been more recently announced. Allyl alcohol is the basic ingredient of a new group of resins and plastics.

Future Oxidation Processes

Well along in the pilot-plant stage are several oxidation processes which should receive their industrial christening within the next five years. Figure 8 shows several of these processes, classified according to the oxidative mechanisms discussed.

The activities of numerous oil companies in the field of the conversion of natural gas to liquid hydro-

carbons through adaptations of the Fischer-Tropsch synthesis has received considerable interest in the past few years. The M. W. Kellogg Company[13] and the Hydrocarbon Research, Inc.[14] have both announced the production of "by-product" oxygenated chemicals accompanying the synthesis of high-octane gasoline and diesel-oil fractions.

P. C. Keith of Hydrocarbon Research, Inc.[14] has announced that the first application of the Hydrocol process is to be made for Carthage Hydrocol Company in a plant to be erected at Brownsville, Texas. This plant is being designed to process 64,000 cubic feet of natural gas per day to produce 5800 barrels of motor fuel, 1200 barrels of diesel fuel, and 150,000 pounds per day of crude alcohols.

P. Ryan of The M. W. Kellogg Company[15] states: "A complete Synthol plant to produce a large volume of liquid hydrocarbon, it is presently estimated (April, 1945) would have a pay-out-time of approximately eight years. A combined Synthol and chemical plant, it is presently estimated, would have a pay-out-time of approximately three years." No information is given on quantities or nature of chemicals produced.

A recent summary article on "Fischer-Tropsch Synthesis and the Petroleum Industry"[15] reports that: "In 1923 Franz Fischer and Hans Tropsch reported the reduction of carbon monoxide in the presence of alkali-iron catalysts at 750-840° F. and 1500-2200 psig. The product was a mixture of aliphatic alcohols, aldehydes, ketones, acids, and esters." An accompanying table shows acetic and propionic to be the principal acids, and ethyl and propyl to be the principal alcohols. Appreciable amounts of acetone were reported.

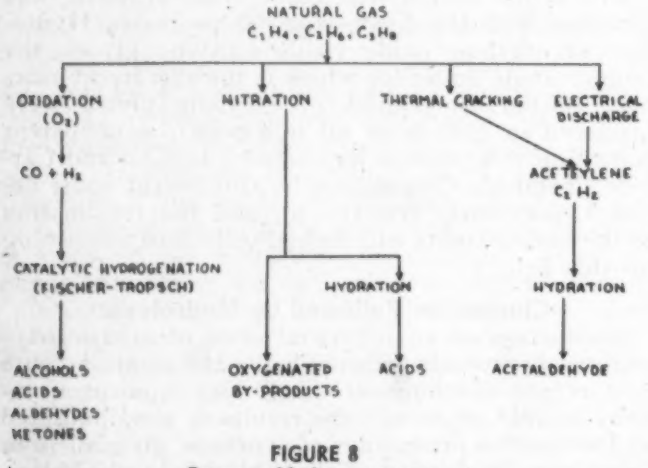


FIGURE 8
Future oxidation processes.

As indicated in Figure 8, the production of these oxygenated derivatives is through the carbon monoxide-hydrogen route, similar to the previously discussed methanol synthesis. It is interesting to note that it is reported that the carbon monoxide-hydrogen mixture will be produced by the partial oxidation of natural gas with oxygen (not air) as the oxidizing medium. This method is said to be more economical than conventional steam-methane reforming, and also gives a hydrogen-to-carbon monoxide ratio closer to the desired value for the optimum synthesis reaction.

It is well to point out that the potential availability of cheap oxygen, perhaps as low as 5 cents per M for large installations, will undoubtedly have an effect on other oxidation syntheses besides the above mentioned Fischer-Tropsch processes. A recent article by W. Lobo of The M. W. Kellogg Company[16] on the production of oxygen by a variation of the so-called Linde-Frankl cycle, confirms this probability.

Acetylene is certainly a potential large-scale natural-gas derivative. Pilot-plant work has been underway at the University of Texas on the so-called silent discharge or high-frequency electric-arc process. Petroleum Chemicals, Inc., announced plans, prior to the war, for the commercial production of acetylene by the Wulff regenerative furnace or high-temperature cracking process, developed through the pilot-plant stage by Tennessee-Eastman.[17] Hydration of acetylene yields acetaldehyde which can be converted into acetic acid, acetic anhydride and numerous other oxygenated chemicals. This acetaldehyde will, of course, have competition from two other oxidation processes—the direct oxidation of paraffin hydrocarbons, and the oxidation of synthetic ethyl alcohol.

Two recent news releases are of particular interest to the oxidation petrochemical field. The September, 1946 *Chemical and Engineering News*[18] reports that a decision is pending on the erection by Shell Chemical Company of a plant in the Southwest to produce glycerol from propylene. The October, 1946, *Petroleum Processing*[19] summarizes the U. S. Naval Technical Mission's report on the partial oxidation of ethane to ethylene, as was used by the I. G. at Leuna during the war.

Conclusion

It is not being too optimistic from a research standpoint or too pessimistic from a management investment viewpoint to state that processes currently being developed in the petroleum and chemical company research laboratories, may offer strong competition or even antiquate all of the processes discussed in this paper.

To the chemist and chemical engineer this means a continued challenge to utilize our expanding knowledge to develop the newer processes and to meet the economic pressure of this competition.

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Rapid Graphical Method of Estimating Tower Diameter and Tray Spacing Of Bubble-Plate Fractionators

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ALIGNMENT charts are presented for estimating the tower diameter and tray spacing of bubble-plate fractionators. These charts, developed from previously published design procedures, are based on four standard types of tray designs.

The design procedure outlined is intended to insure that vapor capacity is sufficient to avoid excessive entrainment, that liquid capacity is sufficient to avoid flooding, and that the design should require a minimum in investment outlay.

Example calculations are included to illustrate application of the method. Included is a cost study of a typical fractionation case, showing the effect of variation in tower diameter and tray spacing upon tower cost.

IN THE design of bubble-plate fractionating towers, it is important that a combination of tray design, tray spacing, and tower diameter be chosen so that the tower will provide the necessary performance and at the same time require a minimum in investment outlay. The tray design should incorporate a combination of high vapor and liquid capacity per unit tray area, and the tray spacing and tower diameter should be chosen so that entrainment is low, or negligible, and the liquid back-up in the downcomers is below flooding level.

A number of years ago Souders and Brown[1] published a method of estimating tower diameter based on a consideration of maximum-allowable entrainment. This correlation, as well as other similar methods which appeared later, has proven to be a valuable contribution to the literature, but admittedly the method takes no consideration of liquid capacity, which has since become recognized as a very important factor in tower design.

More recently, Kirkbride[2] published a paper including a method of selecting tower diameter and tray spacing based on a consideration of both entrainment and liquid capacity. This method provides an excellent basis for tower design and emphasizes the importance of proper tray design. However, tray designs must be available before the method may be applied, and the calculations required are somewhat time-consuming.

It is the purpose of this article to present a rapid graphical method of estimating tower diameter and tray spacing of bubble-plate fractionators. This method combines the basic principles of both the method of Souders and Brown and that of Kirkbride, but, by the adoption of four standard types of tray designs, the method is reduced to a set of charts the use of which enables rapid estimation of required tray spacings and tower diameters.

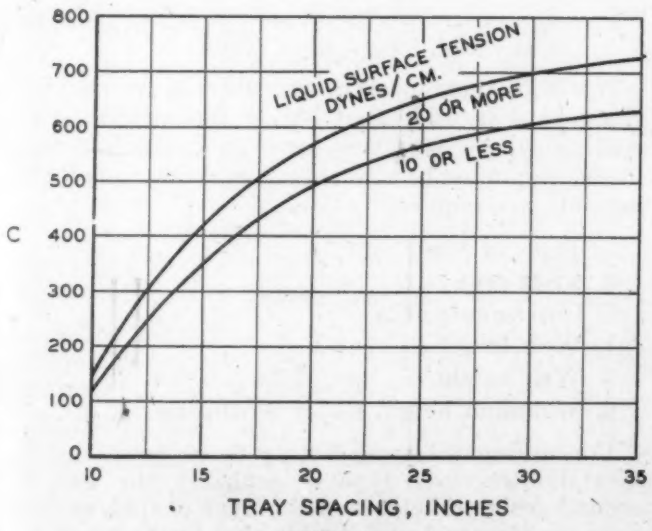


FIGURE 1
Souders and Brown correlation for maximum allowable vapor velocity.

Where Entrainment Is Limiting

There are several correlations between tray spacing and tower diameter at maximum allowable entrainment. One that has been widely used is that of Souders and Brown.[1] This correlation gives the maximum allowable vapor velocity above which excessive entrainment occurs:

$$G_{max} = C\sqrt{\rho_v(\rho_L - \rho_v)} \qquad (1)$$

Souders and Brown found the "constant," C, to be a function of tray spacing, and, to some extent, the surface tension of the liquid, as shown in Figure 1.

In order to facilitate the solution for minimum tower diameter, Equation (1) may be easily converted into the form:

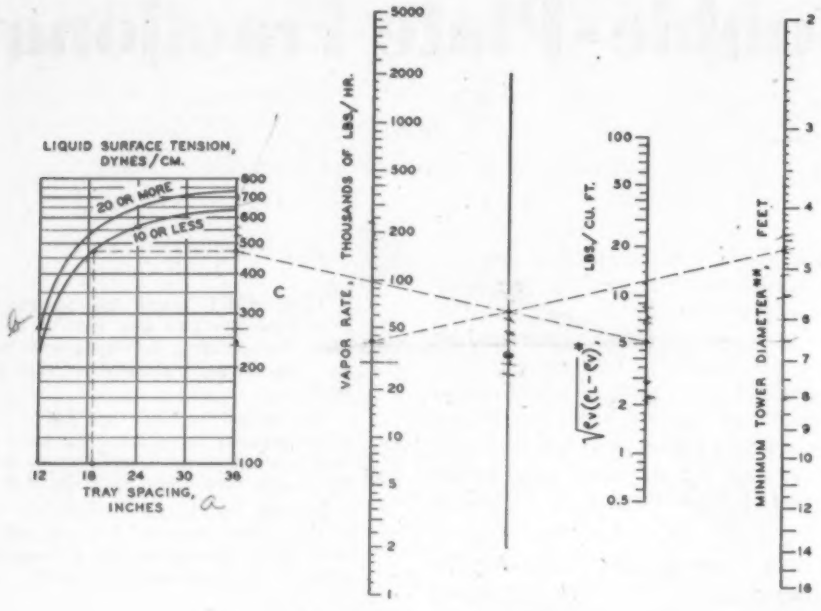
$$(D_{min})^2 = \frac{4}{\pi} \frac{\dot{V}_w}{C\sqrt{\rho_v(\rho_L - \rho_v)}} \qquad (2)$$

With the aid of this equation and the correlation given in Figure 1, the alignment chart shown in Figure 2 was constructed. By means of this chart the minimum tower diameter corresponding to any given tray spacing may be rapidly estimated. The dotted lines on the chart indicate how the chart is used.

It should be pointed out that Figure 2 gives the *minimum* tower diameter from an entrainment standpoint, and the specified diameter should incorporate a safety factor. It is recommended that a 25 percent safety factor based on vapor velocity be used. This

corresponds to about 12 percent safety factor based on tower diameter.

Another entrainment correlation, very similar to the one of Souders and Brown, but preferred by some, is given by Carey.[3] Figure 2 may be used for this correlation also, if values of Carey's "K_v" are multiplied by 3600 to convert to feet per hour and used in place of Souders and Brown's "C."



* ρ_L = LIQUID DENSITY, LB./CU. FT.
ρ_V = VAPOR DENSITY, LB./CU. FT.

** THIS IS THE MINIMUM DIAMETER. THE SPECIFIED DIAMETER SHOULD INCLUDE A SAFETY FACTOR.

FIGURE 2
Minimum tower diameter when entrainment is limiting.

When Liquid Load Is Limiting

Even though a combination of tray spacing and tower diameter is chosen so that the design is satisfactory from an entrainment standpoint, the design may not adequately allow for liquid load. This is discussed by Kirkbride,[2] who presents a design method based on the computation of hydraulic heads and the liquid back-up in downcomers.

According to this analysis, the height of liquid in the downspouts (total hydraulic head) of a segmental-downcomer tray may be estimated as follows:

$$H = 2(h_w + h_{ow}) + h_d + h_{rc} \quad (3)$$

The various terms of Equation (3) are to be estimated as follows:

$$h_{ow} = 30F\left(\frac{L}{W}\right)^{2/3} \quad (4)$$

$$F = \left(\frac{W}{W_1}\right)^{2/3} \quad (5)$$

$$h_d = 0.6\,(u_d)^2 \quad (6)$$

$$h_{rc} = (u_r)^2\left(\frac{\rho_V}{\rho_L}\right) \quad (7)$$

The hydraulic head as calculated by these equations is the liquid head required to cause liquid to flow from one tray down to the one below it, and is equivalent to the height of liquid in the downspout. When the liquid level in the downspout reaches the tray above, the tray floods, causing a sharp reduction in tray efficiency.

This method for calculating the back-up of liquid in the downspouts is based on the presence of liquid, as such, in the downspouts. Actually, the liquid in the downspouts of a fractionator is a froth, and hence its effective density is considerably less than that of pure liquid. For this reason, the liquid back-up in the downcomers required to produce the desired liquid flow will be greater than calculated. In order to provide for this, Kirkbride recommends that the minimum tray spacing be taken as twice the hydraulic head given by Equation (3):

$$S_{min} = 2H \quad (8)$$

When this procedure is followed it is not necessary to apply any additional safety factor.

It will be apparent on examination of the equations given by Kirkbride that before the minimum tray spacing can be estimated for a given fractionator, a tray design must be available. Specifically, the following data are required:

1. Type of tray
2. Riser area
3. Downcomer area
4. Weir length
5. Weir height
6. Minimum height under downcomer.

Concerning the type of tray to be used, the segmental-downcomer type is probably the best all-around design. Sketches of this type of tray, in cross-flow (single-pass) and double-pass forms, are shown in Figure 3. The double-pass design is used in large-

diameter columns (larger than about six feet) in order to shorten the distance the liquid must flow across the plate.

It should be apparent on examination of Figure 3 that there is a definite relationship among riser area, downcomer area, and weir length. For example, the larger the downcomer area is, the longer will be the overflow weir. Similarly, the larger the downcomer area, the less tray area is available for bubble-caps, and hence the smaller will be the riser area.

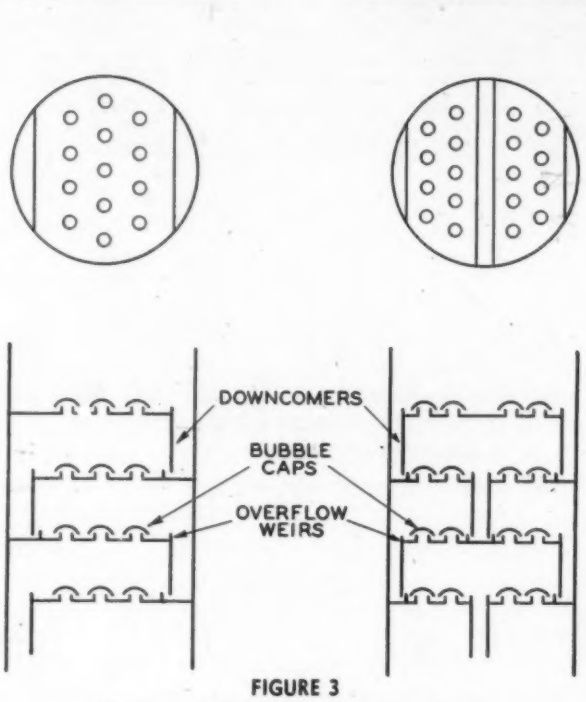


FIGURE 3
Diagrams of segimental-downcomer trays.

For a given type and size of bubble-cap and cap spacing, the ratio between riser area and tray area (excluding downcomer areas) should be constant. Study of the multitude of tray design data available in the TAC Fractionator Study Report[4] reveals that values of this ratio ranging from 0.05 to 0.20 have been used. However, it is believed that the most progressive designers are using a ratio around 0.16 to 0.18. This provides for high vapor capacity per unit tray area, and results in a more economical tower design than the use of the lower ratios.

It will also be noted from Figure 3 that an increase in downcomer area and weir length is possible only at the expense of riser area. Since liquid capacity is largely determined by downcomer area and weir length, and vapor capacity, by riser area, it should be evident that increased liquid capacity can be obtained only at the expense of vapor capacity, and vice versa. Hence the selection of the fraction of tower area to be used for downcomers should be governed by the ratio of liquid and vapor loads to be encountered.

TABLE 1
Standard Tray Designs

	TYPE OF TRAY			
	Cross-Flow			2-Pass
	Low Riser	Medium Riser	High Riser	
Riser Area, Percent of Tower Area	10.0	12.5	15.0	10.0
Downcomer Area, Percent of Tower Area	20.0	14.0	8.0	17.5
Weir Length, Percent of Tower Diameter	87.0	79.7	68.5	84.2
Weir Height, inches	2.5	2.5	2.5	2.5
Minimum Height Under Downcomer, inches	2.5	2.5	2.5	2.5

Table of Nomenclature

C	Constant in Souders and Brown correlation, defined by Equation (1), ft./hr.
D	Tower diameter, ft.
F	Weir formula correction factor for constricting tower wall, defined by Equation (5), dimensionless
G	Vapor mass velocity based on empty tower, lb./hr.-sq. ft.
H	Height (above tray) of liquid in downspouts, in.
h_d	Friction head due to liquid flow under downspout, in. of liquid
h_{ow}	Height of liquid over weir, in.
h_{rc}	Friction head due to vapor flow through risers and caps, in. of liquid
h_w	Height (above tray) of weir, in.
K	Ratio of weir length to tower diameter
K_1, K_2, etc.	Constants defined by Equations (19), (20), (21), and (22)
L	Liquid load, cu. ft./sec.
L_w	Liquid load, lb./hr.
U	Distance from weir to tower wall, in.
U_1	Distance from "effective" weir to tower wall, in.
P	$\left(\frac{V_w}{L_w}\right)^2 \left(\frac{\rho_L}{\rho_v}\right)$, dimensionless
Q	Liquid load, gal./hr.
R	$\sqrt{\rho_v(\rho_L - \rho_v)}$, lb./cu. ft.
S	Tray spacing, center to center, in.
u_d	Liquid velocity under downspout (at narrowest constriction), ft./sec.
u_r	Vapor velocity through risers, ft./sec.
V_w	Vapor load, lb./hr.
W	Weir length (actual), in., except in Equation (9), where it is in feet.
W_1	"Effective" weir length, in., except in Equations (10) and (13), where it is in feet.
α	Ratio of weir length to tower diameter
β	Ratio of riser area to tower area
ρ_L	Liquid density, lb./cu. ft.
ρ_v	Vapor density, lb./cu. ft.

With the above considerations in mind, four standard tray designs were developed, one of which should be suitable for practically any application. These tray designs are given in Table 1.

Before proceeding with the application of the standard tray designs to Kirkbride's method, it is desirable to remove the element of trial-and-error from the calculation of the height of liquid over the weir, as given in Equations (4) and (5). According to Kirkbride's method, it is first necessary to assume a value of h_{ow}, determine W_1 with the aid of his Figure 8, calculate F by means of Equation (5), and finally check the assumed h_{ow} by means of Equation (4). It has been found that it is possible to eliminate h_{ow} between Equations (4) and (5) thus providing a direct solution for F, which can then be used in Equation (4) for h_{ow}. This may be accomplished as follows: Referring to Figure 4, which illustrates the geometry of the weir equations, it is apparent that

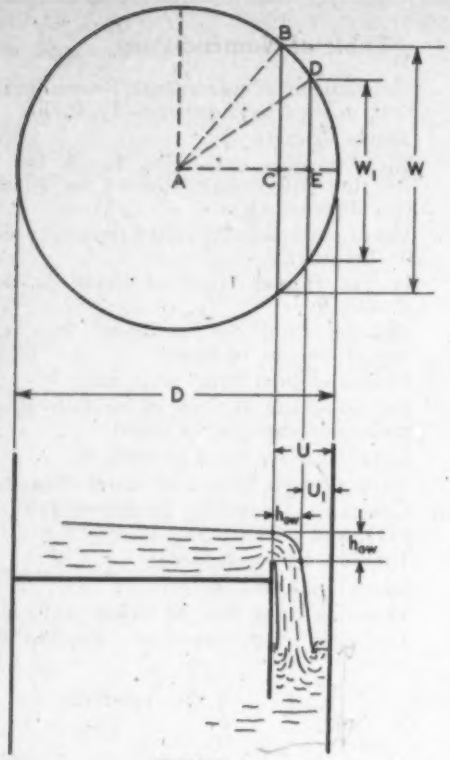


FIGURE 4

Diagram illustrating relationship among variables in wier equations.

application of the Pythagorean Theorem to right triangle ABC results in:

$$\left(\frac{D}{2}-U\right)^2+\left(\frac{W}{2}\right)^2=\left(\frac{D}{2}\right)^2 \tag{9}$$

Similarly, an analogous treatment of triangle ADE gives:

$$\left(\frac{D}{2}-U_1\right)^2+\left(\frac{W_1}{2}\right)^2=\left(\frac{D}{2}\right)^2 \tag{10}$$

Letting $K=W/D$, Equation (9) may be solved for U/D:

$$\frac{U}{D}=\frac{1-\sqrt{1-K^2}}{2} \tag{11}$$

and observing that $U_1=U-h_{ow}$, Equation (10) may be solved for U_1/D:

$$\frac{U_1}{D}=\frac{1-\sqrt{1-K^2}}{2}-\frac{h_{ow}}{D} \tag{12}$$

Now, combining Equations (10) and (12):

$$\frac{W_1}{D}=\left[1-\left(\frac{2h_{ow}}{D}+\sqrt{1-K^2}\right)^2\right]^{1/2} \tag{13}$$

Or:

$$\frac{W_1}{W}=\frac{1}{K}\left[1-\left(\frac{2h_{ow}}{D}+\sqrt{1-K^2}\right)^2\right]^{1/2} \tag{14}$$

Combining Equations (5) and (14):

$$F=K^{3/8}\left[1-\left(\frac{2h_{ow}}{D}+\sqrt{1-K^2}\right)^2\right]^{-3/8} \tag{15}$$

Solving Equation (15) for h_{ow}/D:

$$\frac{h_{ow}}{D}=\frac{\sqrt{1-K^2/F^8}-\sqrt{1-K^2}}{2} \tag{16}$$

Solving Equation (4) for $L/W^{2.5}$:

$$\frac{L}{W^{2.5}}=\left(\frac{h_{ow}/D}{30\,KF}\right)^{3/2} \tag{17}$$

And combining Equations (16) and (17):

$$\frac{L}{W^{2.5}}=\left[\frac{\sqrt{1-K^2/F^8}-\sqrt{1-K^2}}{60\,KF}\right]^{3/2} \tag{18}$$

Equation (18) is shown graphically in Figure 5. Since L, W, and K are all known in advance for a given tray design, Figure 5 may be used to give the value of F without any use of trial-and-error procedure. This value for F may then be substituted in Equation (4) to give h_{ow}.

In order to facilitate the application of Equations (4), (6), (7), and (18) to the standard tray designs, and to convert to more common units, these equations may be transformed to the following:

$$\frac{h_{ow}}{F}=K_1\left(\frac{Q}{D}\right)^{2/3} \qquad K_1=\frac{6.38\times10^{-3}}{\alpha^{2/3}} \tag{19}$$

$$h_d=K_2\left(\frac{Q}{D}\right)^2 \qquad K_2=\frac{1.91\times10^{-3}}{\alpha^2} \tag{20}$$

$$\frac{h_{rc}}{P}=K_3\left(\frac{Q}{D^2}\right)^2 \qquad K_3=\frac{2.24\times10^{-9}}{\beta^2} \tag{21}$$

$$\frac{L}{W^{2.5}}\times10^6=K_4\left(\frac{Q}{D^{2.5}}\right) \qquad K_4=\frac{7.45\times10^{-2}}{\alpha^{2.5}} \tag{22}$$

The constants in Equations (19) through (22) may be computed from the standard tray designs given in Table 1, and are tabulated below:

	TYPE OF TRAY			
	Cross-Flow			2-Pass
	Low Riser	Medium Riser	High Riser	
$K_1\times10^3$	7.00	7.43	8.21	4.51
$K_2\times10^3$	2.52	3.00	4.06	0.672
$K_3\times10^8$	22.4	14.34	9.96	22.4
$K_4\times10^2$	10.59	13.14	19.20	2.62

It is then not a difficult task to construct alignment charts for the solution of Equations (19) through (22), using the method outlined by Davis.[5] The resulting design charts are given in Figures 6, 7, 8, and 9. To use these charts, a straight edge is placed on the chart aligning the liquid load with the tower diameter, and values of h_{ow}/F, h_d, h_{rc}/P, and F are read on the appropriate scales opposite the straight edge. These values then are substituted in the simple formulae accompanying the design charts to give the minimum tray spacing. According to Kirkbride[2] the use of a minimum tray spacing twice the hydraulic head, as is directed on the charts, allows sufficient safety factor for foaming and contingencies.

Final Selection of Design

As has been stated previously, the selection of tray design, tray spacing, and tower diameter should be based on a consideration of both entrainment and liquid load. It has been shown how the minimum tower diameter may be calculated for a given tray spacing with maximum allowable entrainment. Similarly, it has been shown how the minimum tray spacing may be calculated for a given tray design and tower diameter with maximum allowable liquid loading. However, it should be evident that there is more than one combination of these factors (tray design, tray spacing, and tower diameter) which is satisfactory with respect to both entrainment and liquid load. The optimum combination is obviously that corresponding to a minimum in tower cost. In a critical

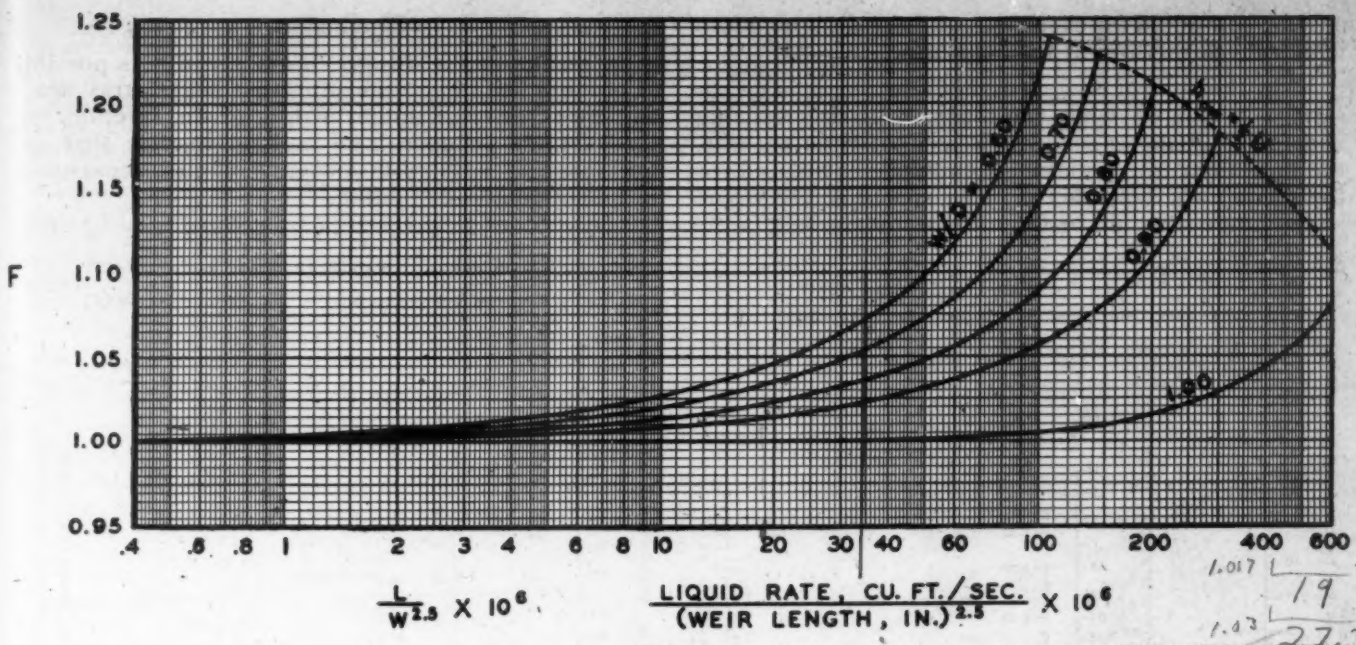


FIGURE 5
Weir formula correction factor for constricting tower wall.

case it actually may be desirable to make an economic study to determine the optimum design. However, for most applications (especially in the case of estimates, for which this method was specifically developed), a few simple principles will serve to provide a basis for the final design selection.

For towers six feet in diameter and larger, it is generally best to employ a two-pass tray design. This serves a two-fold purpose: the distance the liquid must flow across the tray is shortened, and the effective weir length is increased without appreciable increase in downcomer area. About the only case where it would be desirable to use a cross-flow tray for a large column is where the vapor load is exceedingly large as compared to the liquid load, and the relatively high riser area available in the "high-riser," cross-flow tray (Table 1) is indicated.

For towers less than six feet in diameter, the cross-flow tray design is recommended. It may be desirable to use the two-pass tray, but usually it is not worth the additional fabrication cost. In regard to which of the three cross-flow tray designs is best, this is governed by the relative values of vapor and liquid loads. For the general fractionation case, the medium riser design is recommended, but for cases where the vapor-to-liquid load ratio is exceptionally large or small, the high or low riser tray design, respectively, is recommended. In case of doubt as to which tray design should be used, the minimum tray spacing

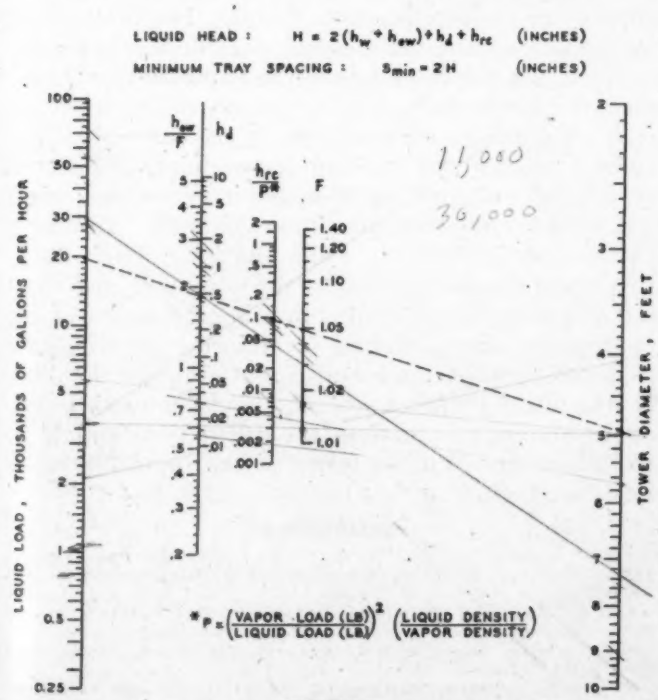

LIQUID HEAD : H = 2(h_w + h_ow) + h_d + h_rc (INCHES)
MINIMUM TRAY SPACING : S_min = 2H (INCHES)
LIQUID LOAD, THOUSANDS OF GALLONS PER HOUR
TOWER DIAMETER, FEET
F
1.40
1.20
1.10
1.05
1.02
1.01
*P = (VAPOR LOAD (LB)/LIQUID LOAD (LB))^2 (LIQUID DENSITY/VAPOR DENSITY)

FIGURE 6
Minimum tray spacing when liquid load is limiting for cross-flow trays with low riser area.

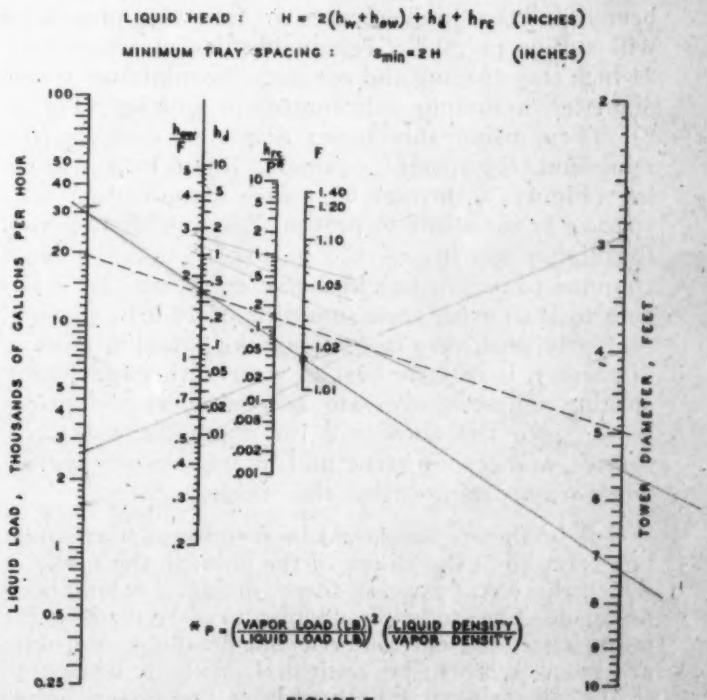

LIQUID HEAD : H = 2(h_w + h_ow) + h_d + h_rc (INCHES)
MINIMUM TRAY SPACING : S_min = 2H (INCHES)
LIQUID LOAD, THOUSANDS OF GALLONS PER HOUR
TOWER DIAMETER, FEET
F
1.40
1.20
1.10
1.05
1.02
1.01
*P = (VAPOR LOAD (LB)/LIQUID LOAD (LB))^2 (LIQUID DENSITY/VAPOR DENSITY)

FIGURE 7
Minimum tray spacing when liquid load is limiting for cross-flow trays with medium riser area.

may be computed for each type, and the design chosen which gives the lowest tray spacing.

After the type of tray design is selected, it is necessary to decide on what combination of tray spacing and tower diameter should be used. If time permits, the minimum tower diameter could be calculated for the whole range of practical tray spacings. Over part of the range it would be found that entrainment is the

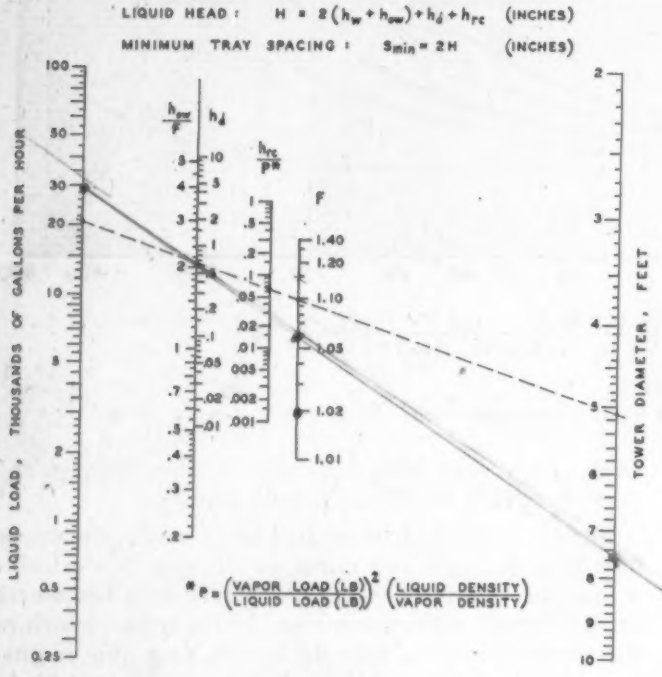

LIQUID HEAD : H = 2(hw + how) + hd + hrc (INCHES)
MINIMUM TRAY SPACING : Smin = 2H (INCHES)
LIQUID LOAD, THOUSANDS OF GALLONS PER HOUR
TOWER DIAMETER, FEET
F
1.40
1.20
1.10
1.05
1.02
1.01
*P = (VAPOR LOAD (LB)/LIQUID LOAD (LB))² (LIQUID DENSITY/VAPOR DENSITY)

FIGURE 8

Minimum tray spacing when liquid load is limiting for cross-flow trays with high rider area.

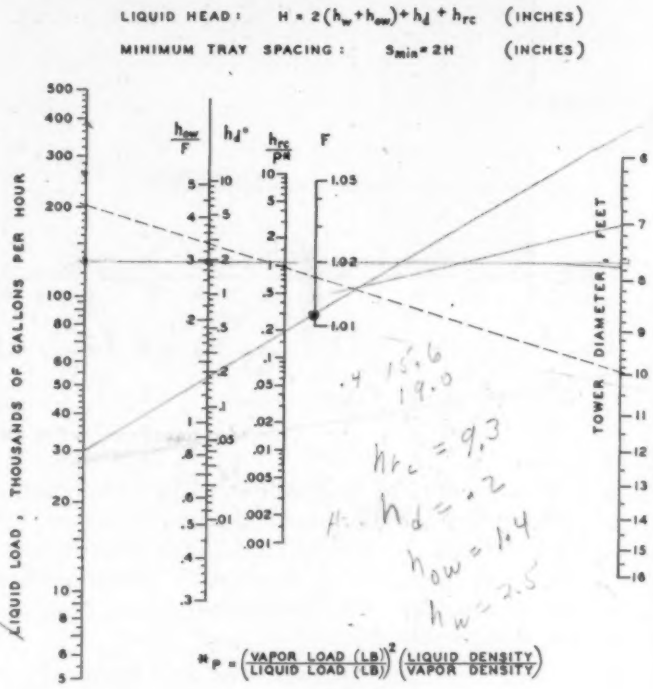

LIQUID HEAD : H = 2(hw + how) + hd + hrc (INCHES)
MINIMUM TRAY SPACING : Smin = 2H (INCHES)
LIQUID LOAD, THOUSANDS OF GALLONS PER HOUR
TOWER DIAMETER, FEET
F
1.05
1.02
1.01
*P = (VAPOR LOAD (LB)/LIQUID LOAD (LB))² (LIQUID DENSITY/VAPOR DENSITY)

FIGURE 9

Minimum tray spacing when liquid load is limiting for double-pass trays.

limiting factor, and over the rest of the range, that liquid load is limiting. (This will be clear from the example to follow.) Then a final selection could be made on a basis of these findings. However, it has been found that in most cases the following procedure will suffice to give a reasonable design: Assume a 24-inch tray spacing and compute the minimum tower diameter, assuming entrainment is limiting (Figure 2). Then, using this tower diameter, compute the minimum tray spacing, assuming liquid load is limiting (Figures 6 through 9), to see if the 24-inch tray spacing is sufficient to prevent flooding. If it is not, the higher spacing should be used. For very small columns (3 feet or less in diameter), it may be desirable to start with an assumption of 18-inch spacing. Similarly, with very large columns (12 feet or more in diameter), it may be best to start with 30-inch tray spacing. These figures are, of course, very approximate, since the allowance for manholes, assembly, service, and certain structural limitations may necessitate tray spacings other than these.

One further point should be mentioned. Care must be exercised in the choice of the point in the tower at which these tray spacing-tower diameter calculations are made. The study should, of course, be made at the point where the entrainment and flooding tendencies are most likely to be critical. Usually it is best to make calculations at both ends of the tower, unless the vapor and liquid loads indicate definitely which end of the tower is the more critical.

Conclusions

By means of the design charts given it is possible to obtain a rapid solution for tray design, tray spacing, and tower diameter for a given fractionator, absorber, or stripper. The method insures that entrainment is negligible and that liquid capacity is sufficient to avoid flooding.

The recommended design procedure may be summarized as follows: Select the tray design from one of the four given in Table 1. If the tower is estimated to be more than 6 feet in diameter, choose the two-pass tray. If the estimated diameter is less than 6 feet choose one of the cross-flow designs. For the general fractionation case, the medium riser design is recommended, but for cases where the vapor-to-liquid load ratio is exceptionally large or small, the high or low riser tray design, respectively, is recommended. Assume a 24-inch tray spacing (or perhaps, 18-inch for very small columns, or 30-inch for very large ones) and compute the minimum tower diameter, assuming entrainment is limiting, using Figure 2. Then, using this tower diameter, compute the minimum tray spacing, assuming liquid load is limiting, by means of the appropriate chart, Figures 6 through 9, to see if the assumed tray spacing is sufficient to prevent flooding. If it is not, the higher spacing should be used. In the application of this method, the calculations should be made at the point in the tower where liquid and vapor loads are highest.

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[3] J. S. Carey, Chem. & Met. Eng., **46**, 314 (1939), "Plate Type Distillation Columns."

[4] Petroleum Industry War Council, Technical Advisory Committee, Report FMC-11, "Study of Light Hydrocarbon Fractionating Towers," undated, but issued in December, 1945, and January, 1946.

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Example Calculation

In the following example, the calculations are far more detailed than would ordinarily be necessary. But in order to illustrate more fully the theory behind this design method, the relationship between tray spacing and tower diameter was determined under entrainment-limiting and liquid load-limiting conditions over the whole range of reasonable tray spacings for all four tray designs. In addition, a cost study was made to find the optimum combination of tray design, tray spacing, and tower diameter. Elsewhere in this article principles are presented whereby a satisfactory design can be reached with only a fraction of this amount of work.

The example fractionator selected for study may be summarized as follows:

Example Fractionator
Summary of Process Design

Type of fractionator ..... Deisobutanizer

Material balance

Compositions

Feed	55 mol % iC_4
Distillate	95 mol % iC_4
Bottoms	95 mol % nC_4

Flowrates	Mol./hr.	Lb./hr.	GPH at 60°F.
Feed	394.4	22,900	4,800
Distillate	227.6	13,220	2,810
Bottoms	166.8	9,680	1,990
Liquid			
Above feed	1,650	95,800	20,400
Below feed	2,044	118,800	24,440
Vapor	1,878	109,000	

Operating Conditions	Pressure, Psia	Temperature, °F.
Top plate	124	137
Feed plate		149
Bottom plate	129	165

Number of trays 53

In the calculations to follow, no account will be taken for the effect on plate efficiency of tray design, entrainment, and the attendant variables of tray dynamics. Since so little specific knowledge is available on this subject, it was thought best to assume that the required number of plates is constant.

With the aid of Figure 2, the minimum tower diameter may be estimated for a number of tray spacings, assuming entrainment is limiting, as follows:

Minimum Tower Diameter When Entrainment Is Limiting

Point of evaluation	Tower bottom
Pressure	129 psia
Temperature	165°F.
Key component	n-butane
Surface tension	6.5 dynes/cm.
Liquid density	31.8 lb./cu. ft.
Vapor density	1.32 lb./cu. ft.
$R = \sqrt{\rho_v(\rho_L - \rho_v)}$	6.35 lb./cu. ft.
Vapor rate	109,000 lb./hr.

Tray spacing, inches	12	14	18	24	36
Minimum tower diameter, feet,					
From Figure 2	9.95	8.40	7.00	6.30	5.90
Including Safety Factor	11.15	9.40	7.85	7.05	6.60

Then with the aid of Figures 6 through 9, the minimum tray spacing may be estimated with each of the four standard tray designs for a number of tower diameters, assuming liquid load is limiting:

Minimum Tray Spacing When Liquid Load Is Limiting:

Point of evaluation	Tower bottom
Pressure	129 psia
Temperature	165°F.
Key component	n-butane
Liquid density	31.8 lb./cu. ft.
Vapor density	1.32 lb./cu. ft.
Liquid load	118,800 lb./hr. or 28,000 gph
Vapor load	109,000 lb./hr.

$$P = \left(\frac{V_w}{L_w}\right)^2 \left(\frac{\rho_L}{\rho_v}\right) = \left(\frac{109{,}000}{118{,}800}\right)^2 \left(\frac{31.8}{1.32}\right) = 20.2$$

Cross-Flow Tray, Low Riser

Tower Dia., Feet	5	5.5	6	8	10
h_{ow}/F	2.20	2.10	1.96	1.62	1.40
h_d	0.82	0.66	0.55	0.32	0.20
h_{re}/P	0.30	0.20	0.145	0.050	0.020
F	1.040	1.032	1.025	1.014	1.01
h_w	2.50	2.50	2.50	2.50	2.50
h_{ow}	2.31	2.17	2.01	1.64	1.41
h_w+h_{ow}	4.81	4.67	4.51	4.14	3.91
$2(h_w+h_{ow})$	9.62	9.34	9.02	8.28	7.81
h_d	0.82	0.66	0.55	0.32	0.20
h_{re}	6.05	4.03	2.93	1.01	0.40
H	16.49	14.03	12.50	9.61	8.41
S	33.0	28.1	25.0	19.2	16.8

Cross-Flow Tray, Medium Riser

Tower Dia., Ft.	4.5	5	6	8	10
h_{ow}/F	2.54	2.38	2.11	1.75	1.51
h_d	1.20	0.95	0.65	0.37	0.25
h_{re}/P	0.30	0.20	0.093	0.030	0.0125
F	1.083	1.064	1.044	1.025	1.015
h_w	2.50	2.50	2.50	2.50	2.50
h_{ow}	2.75	2.53	2.20	1.79	1.53
h_w+h_{ow}	5.25	5.03	4.70	4.29	4.03
$2(h_w+h_{ow})$	10.50	10.06	9.40	8.58	8.06
h_d	1.20	0.95	0.65	0.37	0.25
h_{re}	6.00	4.04	1.88	0.61	0.25
H	17.70	15.03	11.93	9.56	8.56
S	35.4	30.1	23.9	19.1	17.1

Cross-Flow Tray, High Riser

Tower Dia., Ft.	4.5	5	6	8	10
h_{ow}/F	2.80	2.60	2.30	1.90	1.64
h_d	1.60	1.30	0.90	0.50	0.33
h_{re}/P	0.185	0.125	0.060	0.019	0.0056
F	1.20	1.14	1.09	1.050	1.031
h_w	2.50	2.50	2.50	2.50	2.50
h_{ow}	3.36	2.96	2.51	2.00	1.69
h_w+h_{ow}	5.86	5.46	5.01	4.50	4.19
$2(h_w+h_{ow})$	11.72	10.92	10.02	9.00	8.38
h_d	1.60	1.30	0.90	0.50	0.33
h_{re}	3.74	2.52	1.21	0.38	0.11
H	17.06	14.74	12.13	9.88	8.82
S	34.1	29.5	24.3	19.7	17.6

Double-Pass Tray

Tower Dia., Ft.	6	8	10	12	15
h_{ow}/F	1.25	1.05	0.90	0.79	0.68
h_d	0.15	0.08	0.05	0.02	0.01
h_{re}/P	0.13	0.041	0.017	0.008	0.0032
F	1.009	1.000	1.000	1.000	1.000
h_w	2.50	2.50	2.50	2.50	2.50
h_{ow}	1.26	1.05	0.90	0.79	0.68
h_w+h_{ow}	3.76	3.55	3.40	3.29	3.18
$2(h_w+h_{ow})$	7.52	7.10	6.80	6.58	6.36
h_d	0.15	0.08	0.05	0.02	0.01
h_{re}	2.63	0.83	0.34	0.16	0.06
H	10.30	8.01	7.19	6.76	6.43
S	20.6	16.0	14.4	13.5	12.9

The results of these calculations are then shown graphically in Figure 10. With respect to liquid load-limiting conditions, it will be noted that the double-pass tray allows lower tray spacing, for any given tower diameter, than do any of the cross-flow trays. Hence it would be more economical to employ the double-pass design for towers greater than 6 feet in diameter.

With low tray spacings, up to about 15 inches, it will be observed that the tower diameter demanded by liquid load is greater than that required to avoid entrainment. Hence liquid load is limiting in this range. However, between 15- and 20-inch tray spacings, considering the double pass tray, it is entrainment which is limiting; for the tower diameter required to avoid entrainment is greater than that demanded to prevent flooding. Then, with tray spacings above about 20 inches, entrainment is limiting, regardless of which tray design is used. It should be evident, then, that the underlined curve in Figure 10 indicates, for any given tray spacing, the smallest tower diameter, and hence the cheapest tower design, that is satisfactory from both entrainment and liquid-load standpoints.

In order to determine which combination of tray spacing and tower diameter, along the underlined curve in Figure 10,

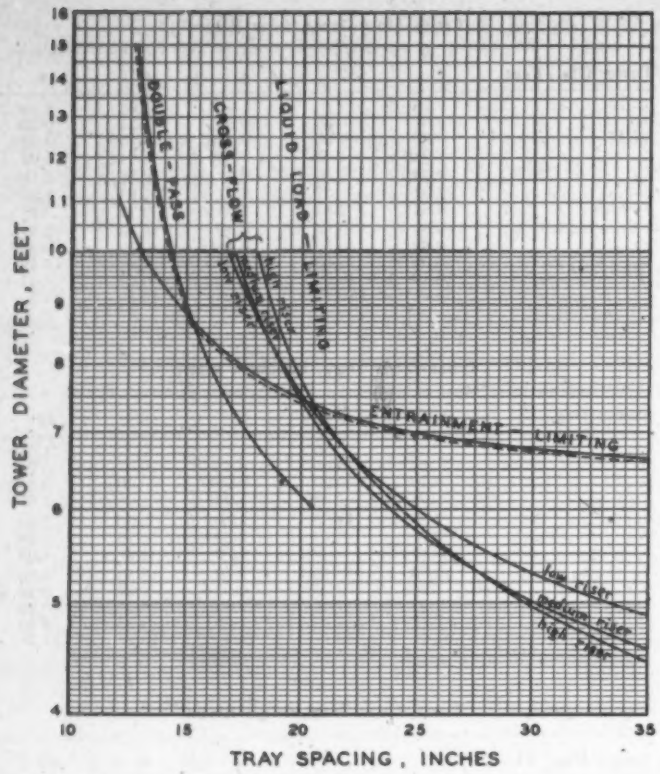


FIGURE 10

Relationship between tray spacing and tower diameter under entrainment-limiting and liquid load-limiting conditions for example fractionation case. (The underlined curve indicates for any given tray spacing, the smallest tower diameter that is satisfactory from both entrainment and liquid load standpoints).

is the optimum, the tower cost for a number of points along this curve were estimated, and the results are as follows:

Tray spacing, in.	12.9	13.5	14.4	15.3	20	25	30	35
Tower diameter, ft.	15.0	12.0	10.0	8.7	7.5	7.0	6.75	6.60
Tower cost, thousands of dollars	77	52	37	29.5	25.0	23.9	24.3	25.0

These costs are shown graphically in Figure 11. It will be noted, there, that a minimum in cost occurs at about 24-inch tray spacing. This corresponds to a 7-foot tower diameter.

Hence it may be concluded that the best tower design for this fractionation case may be summarized as follows:

Tray design	**Standard double-pass**
Tray spacing	24"
Tower diameter	7.0'

This design is safe from both entrainment and liquid load standpoints, and also corresponds to a minimum in cost.

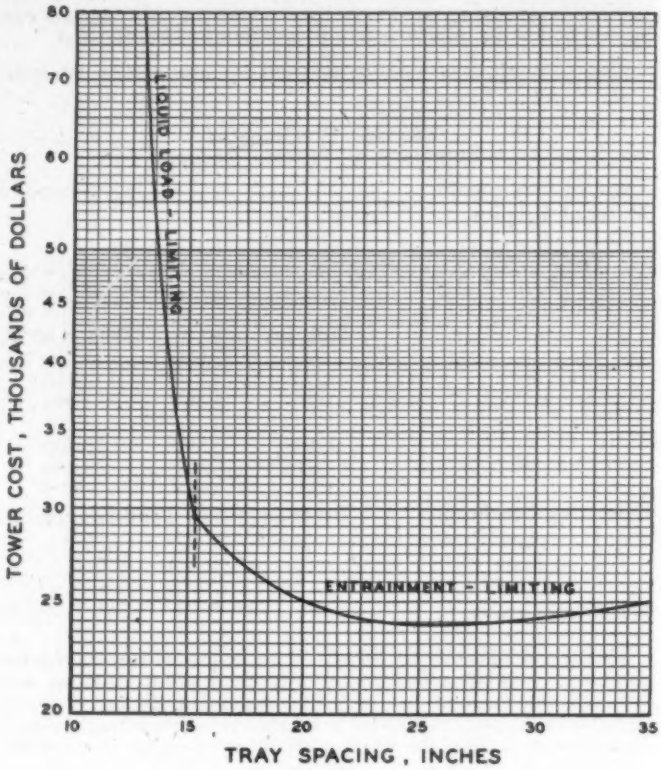


FIGURE 11

Effect of tray spacing on fractionator cost for example fractionation case. (Cost includes fabrication but not erection).

ANALYSIS OF
Rigid Knee-Braced Bents
USED IN PETROLEUM AND CHEMICAL PLANTS

WESLEY H. BLANK
Consulting Engineer

I. General

A COMMON type of structure used in chemical plants and oil refineries is the steel knee-braced, single- or double-bay framework. These structures, usually two or three stories high, are employed as pipe galleries with their motor-driven or hand-operated valves serviced from access walkways. Not infrequently much light tank work, pressure vessels, heat exchangers and other equipment are packed in tightly on the structure. Because of interference of cross or "K" bracing with the piping, expansion loops and the operating platforms, knee braces are employed to stiffen the framework at the column-beam joints. This stiffening is especially needed to resist the effects of sidethrust due to pipe stresses, wind, and equipment expansional or contractional forces created by hot fluids and gases. Figure 1

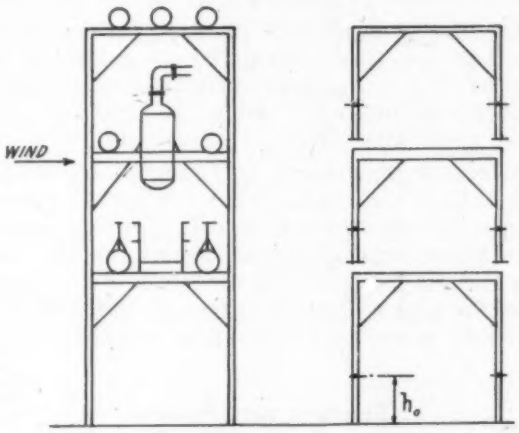


FIGURE 1
Typical Problem

shows a typical knee-braced bent found in actual plants.

The analysis of such a framework is statically indeterminate. This is due to the unknown amount of restraint at the beam-column joint which causes end beam and column moments. These end moments vary with the position and the slope of the knee braces and upon the relative stiffness of the cross beam to the column.

Approximate methods in use for calculating the bent stresses start with the erroneous assumption of zero moment at the column-beam joint and with the location of the point of inflection on the column assumed at various places usually half way up from the column base to the knee-brace-column joint. Although moments could be brought to zero by hinging the joints, the conventional riveted or welded connection permits much bending by restraint to rotation. In case of monolithic-concrete construction there are always end moments present. Quoting Professor Ketchum on knee-braced bents, we note, "Stresses are statically indeterminate and cannot be calculated without taking into account the deformations of the members themselves."

Since this common type of framework, largely developed as a principal type for open structures, cannot be safely approximated, this article is intended to offer charts, tables and simple procedures to solve the moments, shears and direct stresses quickly and accurately. The basis for the charts are formulae derived by least-work principle to a segregated bent and loads are applied one at a time for separate analysis.

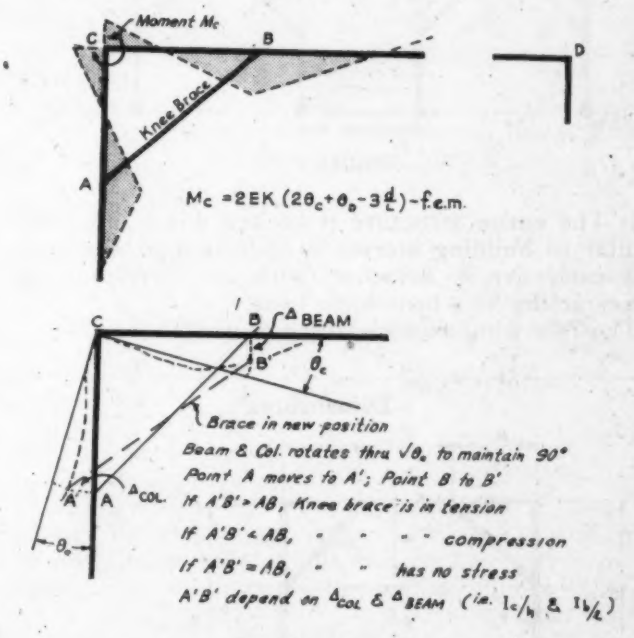


FIGURE 2

Deformation of the bent under loading is indicated in Figure 2. The amount of bending at the column-beam joint causes a corresponding degree of rotation of the column and beam equally to maintain the 90-degree fabricated joint. It will be observed that the knee brace has moved to a new position and changed length by virtue of the deflection of the beam at point B and because of the lateral displace-

ment of the column at point A. The relative magnitude of these deflections, depending on the stiffness of the members involved, causes a shortening or lengthening of the knee brace AB, as indicated in its new position A′B′. The change of length is a measure of the stress in the brace.

II. Plan of Attack

To write out and solve least-work equations for every problem that occurs is an infinitely tedious task. Therefore the writer has prepared a plan of attack and a standardization of dimensions with adopted nomenclature and basic criteria, which permits any problem to be analyzed by the same set of charts and formulae. This article will be confined to a single-bay structure of any number of tiers in height. Derivations of formula will be omitted and results only will be tabulated. The following are the criteria and conditions mentioned.

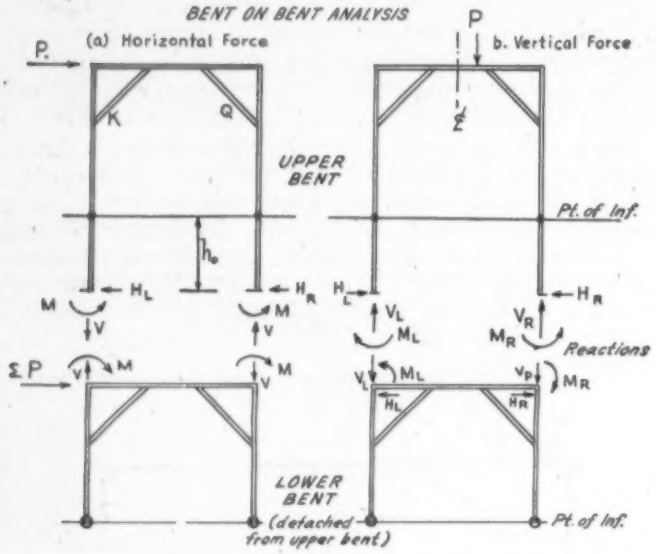


FIGURE 3

1. The entire structure is broken down into tiers similar to building stories as indicated in Figure 3 and each tier is detached with its corresponding forces acting as a bent upon bent.

The following nomenclature is used:

2. A typical bent is shown in Figure 4 with the adopted nomenclature. To reduce unnecessary variables to a minimum, all knee braces are to be at 45 degrees, thereby making equal intercepts on the column and beam. Also both column sizes are to be the same.

3. The point of inflection or the point of zero moment on the column must next be located. The height "h_o" is obtained by a formula figured on a column base of fixity or infinite restraint. Such an assumption errs on the safe side and a comparison of the formula derived,

$$h_o = \frac{nL(3h-a)(h-a)+(L-2a)^2 h}{2nL(3h-2a)+(L-2a)^2}$$

is made later in this article to those derived in text books by Johnson, Milo Ketchum and Isami Hiroi.

4. The bent is now treated from the point of inflection up as a hinged supported bent. This eliminates the difficulty of obtaining vertical reactions and simplifies the least-work equations by excluding the unknown base moment in the columns.

5. The loading is applied to the bent in the following manner to make separate typical case analyses.

(a) Single loads are applied at points thus:
A horizontal force P at the column-beam joint
A vertical force P anywhere along the beam
(b) Single moment as a force applied
First, at the left column-beam joint clockwise
Second, at the right column-beam joint clockwise
Third, at both of the column-beam joints clockwise

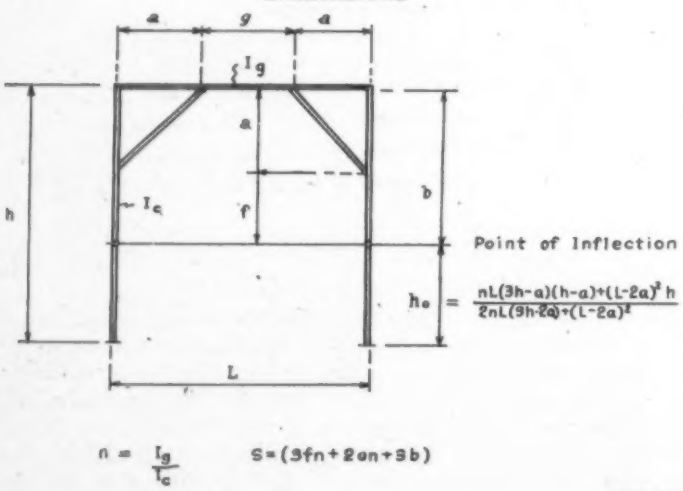
This moment represents the moment brought down by the horizontal shear in the columns of the bent above from point of inflection to base of the column.

6. To set up equations of least work, the knee braces were cut and considered as unknown forces with equal horizontal and vertical components. The components acting were called "K" and "Q" for the left and right knee braces respectively.

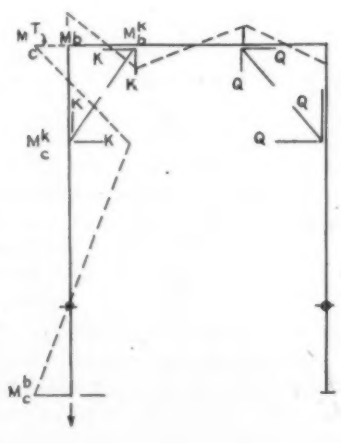
7. After the knee-brace components are found together with the H and (P-H) horizontal forces, all moments and shears are readily figured. Formulae for the above reactions were found for the bent in letters for the loads and dimensions. All derivations are lengthy and will not be given in this article.

8. Charts were next devised to simplify the fore-

Dimensions



Stresses and Forces



Moments
Top of Column....M^t_c
Col. @ Knee Brace.M^k_c
Col. @ Base.....M^b_c
End of Beam.....M_B
Beam @ Knee Br..M^k_b

Knee Braces
Left Hor. & Vert. Components .....K
Right Hor. & Vert. Components .....Q

FIGURE 4

going work for the designer. These charts consist of:

(a) Point of inflection.
(b) Moment in column at column-beam joint due to force of P acting horizontally at joint.
(c) Moments in column at the column-beam joint but due to two equal clockwise moments M acting at each column-beam joint.

III. Point of Inflection Discussed

To readily determine the point of inflection, the cumbersome equation is solved by charts. An initial

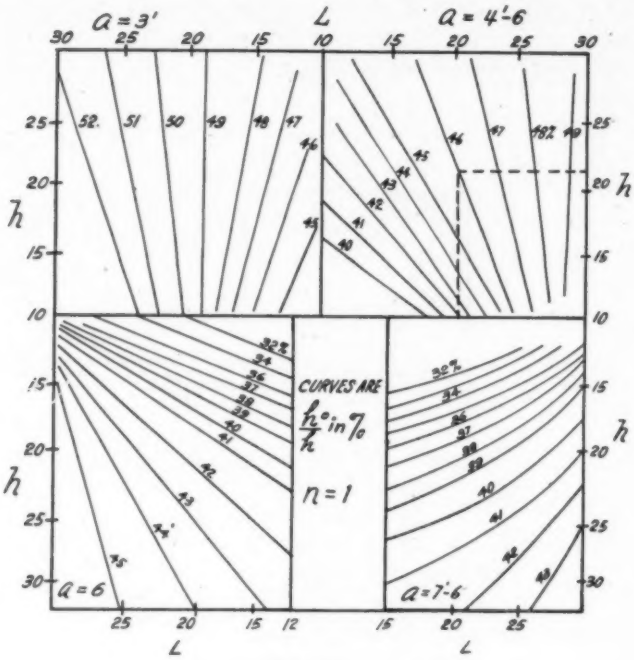


FIGURE 5

set of charts were made by establishing "n" equal to 1, followed by assigning to "a," values of 3' 0"; 4' 6"; 6' 0"; and 7' 6". These four charts to the value of "n" equal 1 were plotted with ordinates as "h" and abscissa as "L" and the resulting curves are percent ratios of h_o/h. These curves are shown in Figure 5.

As many more sets of curves may be constructed by assuming values of "n" with "a" as above. Figures

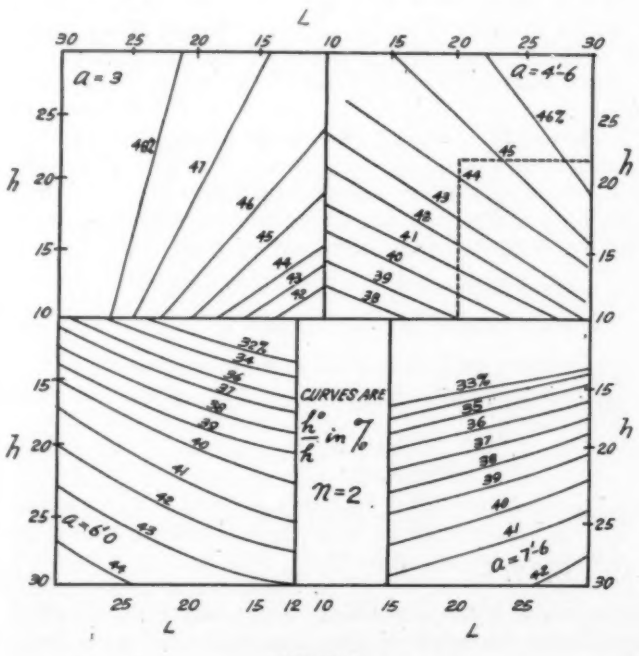


FIGURE 6

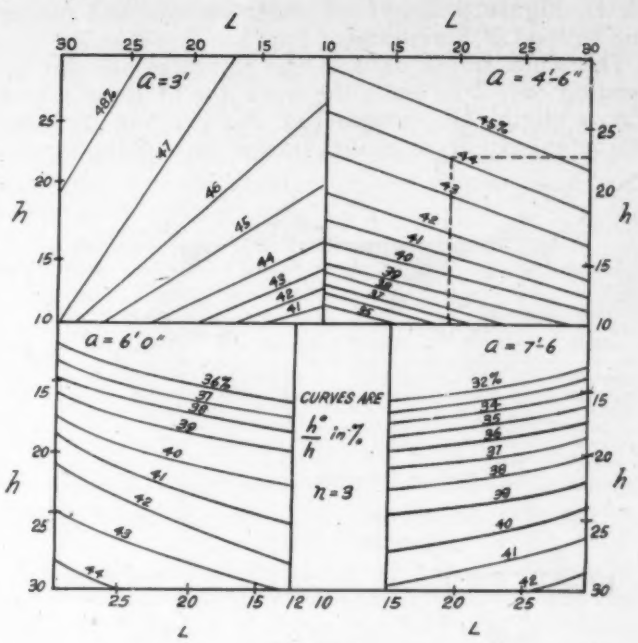


FIGURE 7

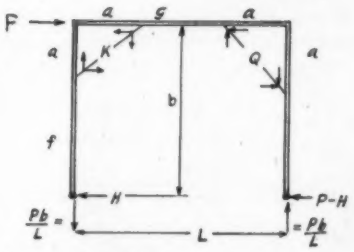
6 and 7 give resulting curves for cases of "n" equal 2 and 3 respectively.

To illustrate the use of the charts consider the following problem:

Let $h = 22'\ 0''$	$L = 20'\ 0''$	$a = 4'\ 6''$
For $n = 1$	$n = 2$	$n = 3$
$h_o/h = 46.1\%$	$h_o/h = 44.4\%$	$h_o/h = 44\%$
$h_o = 10.14'$	$h_o = 9.77'$	$h_o = 9.68'$

To follow the trend in "h," let "n" increase and we find "h_o" varies less and less, and finally approaches $0.5h - .35a$ approximately as "n" approaches infinity. However as "n" decreases, "h_o" rapidly rises for values less than unity. This condition, however, is never met in refinery work, nor in yard pipe supports.

IV. Bent Analysis for a Horizontal Force P at Column-Beam Joint



To solve for:
K—Components of Left Brace
Q—Components of Right Brace
H and P-H—Reactions

A. *Derivation*

The least-work derivation is straight-forward; each expression of work with respect to one unknown variable being differentiated and placed equal to zero. As many simultaneous equations resulted as there were unknowns. They are as follows:

$$(4nb^3 + 6b^2L)\,H + (a^2s)\,K - (a^2s)\,Q - (2nb^3 - 3b^2L)\,P = O$$
$$sH + 2a(n+1)K - (s - ab/L)P = O$$
$$sH - 2a(n+1)Q - (ab/L)P = O$$

RESULTS: $H = P/2$; and $P - H = P/2$

$$K = Q = \frac{P(s - 2ab/L)}{4a(n+1)}$$

where s is a short form for $(3fn + 2an + 3b)$

$M^K{}_C$ —bending at the Column-Brace Joint $= Hf = P/2(f)$

$M^T{}_C$—bending at the Column-Beam Joint $= (Hb - Ka)$

$M^K{}_B$—bending at the Beam Brace Joint $= Hb - Pba/L = Hbg/L$

Vertical reactions are equal and opposite, and =

Pb/L. Figure 8 shows all the moments and forces due to load P horizontal.

The work terms used in the formulae are due to bending only. For bents the work due to direct stress was negligible in comparison. No bending in knee braces existed from model frames put under stress.

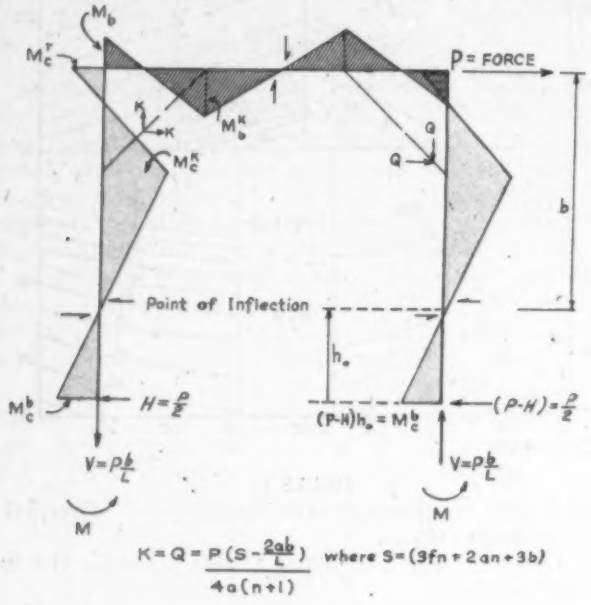


FIGURE 8

V. Moment Chart Due to Horizontal Force "P"

(a) The chart has been prepared to obtain M^t_c, being the moment at the column-beam joint and equal to Hb-Ka. Substituting for Hb its value Pb/2 and for Ka its equal

$$M^t_c = \frac{Pb}{2}\left\{1 - \frac{\left(\frac{s}{b} - \frac{2a}{L}\right)}{2(n+1)}\right\} = \frac{Pb}{2}(1-\beta+\alpha) = M'\Delta$$

where M′ will be taken as Pb/2 and Δ as a percent of M′ in decimal form and when negative, indicates that M^t_c is counterclockwise, and

$$\alpha = \frac{a/L}{n+1} \qquad \beta = 1.5 - \frac{an/b}{2(n+1)} = \frac{s/b}{2(n+1)}$$

$$K = \frac{M'(1-\Delta)}{a}$$

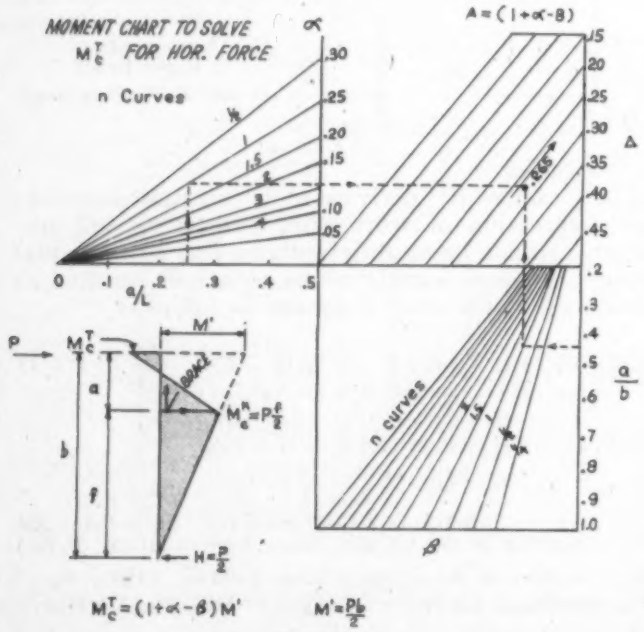


FIGURE 9

(b) Construction of the chart (refer to Figure 9). This is a combination of 3 graphs to obtain:

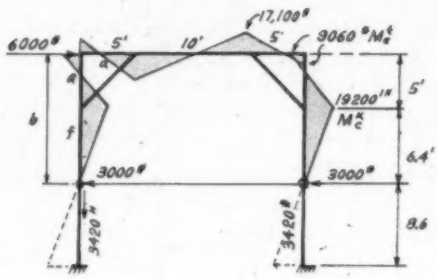
1. With "n" held constant, the first term α was plotted as ordinates using a/L as abscissae. By assigning different values to "n" a series of straight converging lines were recorded on the first graph.

2. With "n" again constant, the second term β was plotted as abscissae and a/b as ordinates. Another series of "n" lines were made. This became the second part of the chart.

3. Using the term α as ordinates and β as abscissae, a series of $(1+\alpha-\beta)$ terms called Δ are obtained.

(c) Example of use of chart

Given:



$$L = h = 20'\,0'' \qquad n = 1$$

$$a/b = 0.44 = \frac{5}{11.4}$$

$$a/L = 0.25 = 5/20$$

$$M' = \frac{6000}{2}(11.4) = 34200'\#$$

From the chart using above values

$$\Delta = -0.265 \qquad M^t_c = .265(34200) = 9060.'\#$$

M^t_c is counterclockwise

$$M^k_c = 3000\#\,(6.4') = 19200'\#$$

$$Q = K = \frac{34200\#}{5}(1.265) = 8650\#$$

$$M^k_b = 34200 - 3420 \times 5 = 17100'\#$$

VI. Determination of Knee Brace Stresses and Bent Moments Due to Applied Joint Moments

Superimposed joint moment loading originates from the shear from an upper bent and this moment is equal to Hh_o. That is the horizontal shear times the distance from the point of inflection to the base of the column. There are four conditions of moment loading:

1. A single moment clockwise applied at the left column beam joint of magnitude M. The theory of least work was again applied and the three resulting equations after applying the first derivative of work with respect to each unknown to zero are:

$$Hs + 2a(n+1)K - (3 - a/L)M = O$$

$$Hs - 2a(n+1)Q - (a/L)M = O$$

$$(4nb^3 + 6b^2L)H - a^2s(Q-K) - 3bLM = O$$

where s is the short form for $(3fn + 2an + 3b)$,

$$K = \frac{M(3 - a/L) - Hs}{2a(n+1)} \qquad Q = \frac{Hs - (a/L)M}{2a(n+1)}$$

$$Q - K = \frac{2Hs - 3M}{2a(n+1)} \qquad H = \frac{1.5[2bL(n+1) - as]M}{(4b^3n + 6b^2L)(n+1) - as^2}$$

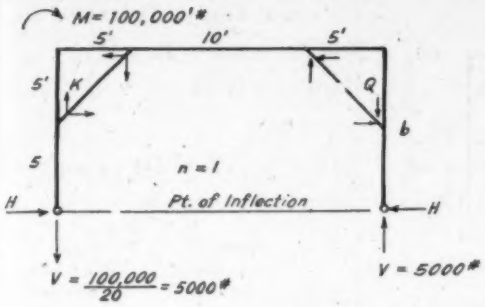
$$V = M/L$$

For this type of loading only, the following are significant features of the reactions and knee-brace stresses found. Both V and H are equal and opposite

with H acting inward. K acts in tension while Q is in compression and they are not equal.

The following example will illustrate the use of the formulae:

PROBLEM



L = 20' 0"

b = 10'

a = 5'

Pf. of Inflection and n assumed

S = 15 + 10 + 30 = 55

REACTIONS

$$H = \frac{1.5(2\times 10\times 20\times 2 - 5\times 55)(100{,}000)}{(4\times 1000\times 1 + 6\times 100\times 20)2 - 5\times 3025} = 4670\#\ \text{Inward}$$

$$Q = \frac{4670\times 55 - \frac{1}{4}\times 100{,}000}{10(1+1)} = 11593\#$$

$$K = \frac{100{,}000(3-\frac{1}{4}) - 4670\times 55}{10(1+1)} = 908\#$$

KNEE BRACE STRESSES

Left = $\sqrt{2}K = 1280\#$ Tension

Right = $\sqrt{2}Q = 16300\#$ Compression

MOMENTS AT LEFT COLUMN

$M^K_c = Hf = 4670\times 5' = 23350'\#$

$M^T_c = Hb + Ka = 4670\times 10 + 908\times 5 = 51240'\#$

$M_B = M^T_c - M = 51240 - 100000 = -48760'\#$

AT RIGHT COLUMN

$M^K_c = 23350'\#$

$M^T_c = Hb - Qa = 4670\times 10 - 11593\times 5 = -11260'\#$

$M_B = -M^T_c = +11260'\#$

MOMENTS ALONG THE BEAM

1. At the left knee brace
   $M^K_b = 100000 - 5(5000) - 46700 = 28300'\#$
2. At the right knee brace
   $M^K_b = 46700 - 25000 = 21700'\#$

Figure 10 shows the moments plotted on the tension of the members.

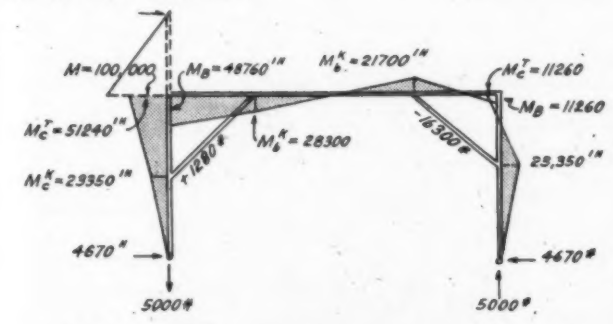


FIGURE 10

2. A second condition is the case when the single moment is applied at the right column-beam joint. It is obvious that the results are just the opposite to Case 1 with Q taking the value of K, but H and V being the same values. One important fact is that H acts outward but the kind of stresses in the knee braces does not reverse, so that the left brace is still in tension and the right is in compression. There is no change in the direction of V.

3. The third case is for Two Moments applied one at each joint. Naturally this is merely Case 1 and 2 combined.

V now becomes equal to 2M/L, whereas H = Zero

K equals Q and both equal $\frac{M(3-2a/L)}{2a(n+1)}$

K is in tension while Q is in compression

4. This is not a new case but the three foregoing conditions applied to counter-clockwise moments which give reverse results to clockwise moment and the same magnitude.

Summary of the Effects of Moment Loading Cases

Case	Moment Loading at Left Joint	Moment Loading at Right Joint	Manner	H Acts	Knee Brace Stress Left	Knee Brace Stress Right
1	#		Clockwise	Inward	Tension	Compression
2		#	Clockwise	Outward	Tension	Compression
3	#	#	Clockwise	Zero	Tension	Compression
4a	•		Counter Clock	Outward	Compression	Tension
4b		•	Counter Clock	Inward	Compression	Tension
4c	•	•	Counter Clock	Zero	Compression	Tension

VII. Moment Charts for the Double Moment Condition Clockwise

No charts have been prepared for conditions of single-moment loading as the labor incurred and the complicated nature of these graphs is far in excess of the time in solving the equations for these infrequent loading cases. In general bents are loaded with double moments and of equal magnitude and it is this common case that lends itself most frequently to the use of charts. See Figure 11.

NOTE:

Since H = O then $M^T_c = Ka = \frac{M(3-2a/L)}{2(n+1)}$

(a) equals r%(M)

where r equals $\frac{(3-2a/L)}{2(n+1)}$

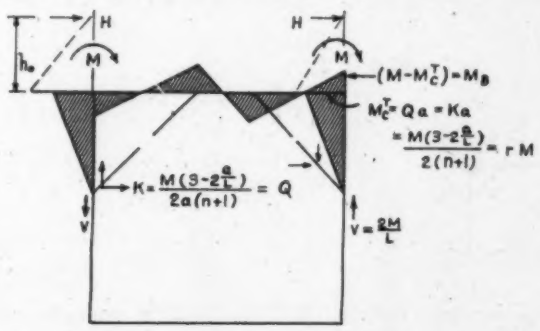
With a/L as abscissae and r% as ordinates, we get a series of curves for assigned values of n from ½ to 4. $M_B = M - M^T_c$ $\quad M^K_b = Mg/L$

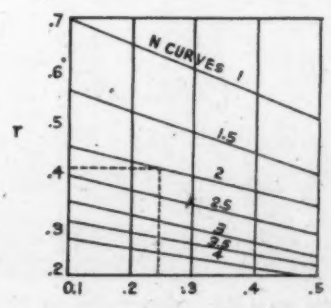
In connection with Figure 11 is given an illustrative problem.

FIGURE 11

VIII. Vertical Loading on Bent Analyzed

In actual conditions the beam is loaded by pipes and much equipment. As these loads may occur anywhere, every point along the beam must be investi-





EXAMPLE

L = 20' a = 5' a/L = .25

M = 60'K n = 2 g = 10'

Find r = .416

$M^T_c = 25'K$, $M_B = 35$ } = 60'K = M

$M^K_B = M\,g/L = 30'K$

gated. However for these conditions only two cases of loading need be analyzed.

A single load P is applied:
(a) First, at any point between the column and the knee-brace connection to the beam at the left end. (The reverse results would be obtained for the right end of the beam.)
(b) Second, at any point between the knee-brace-beam joints along the beam.

Special conditions are when load P is applied directly over each or both knee braces and at the center of the span.

Formulae for H, Q, K must be derived by least-work equations and the results are complicated expressions which do not lend themselves satisfactorily to graphic solution. However, there is so little difficulty and time expended in direct solution by formular that this method is recommended. Of course it is necessary to take each load separately and add their effects.

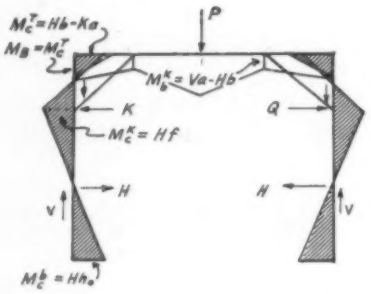
Reactions at the point of inflection have the following characteristics:

Vertical forces can be solved by statics in the usual way.

Horizontal forces are equal and opposed and both pull inward.

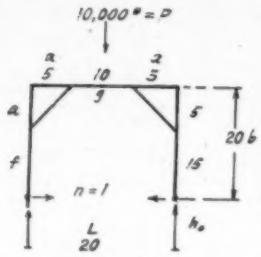
Knee braces are all under compression.

Figure 12 tabulates all derived values of H, Q, K, for the cases taken above, which enables a load anywhere on the span to be fully analyzed.



IX. Illustrative Problems

(a) Vertical Loading Problem.
(b) Multiple Tier Bent Problem.



(A.) *Illustrative Problem of a Vertical Load at Different Points.*

$s = 3fn + 2an + 3b = 115$

$2a(n+1) = 20$

$a^2s = 2875$

$a/L = 1/4 \quad a^2L = 5/4 \quad a + g = 15$

$ab = 100$

	Case 1 P at Left Knee Brace	Case 2 P at Right Brace	Case 3 P at both Braces
$H = \dfrac{10{,}000\#\left[(300\times 15) - \dfrac{2875}{4}\right]}{800(40+60) - \dfrac{5\times(115)^2}{2}}$	$= 805\#$	$805\#$	$1610\#$
$Q = \dfrac{805\times 115 - 10{,}000\times 5/4}{20}$	$= 4000\#$	$2750\#$	$6750\#$
$K = \dfrac{805\times 115 - 10{,}000\times 1/4(15)}{20}$	$= 2750\#$	$4000\#$	$6750\#$
$V_L = 10{,}000\times\dfrac{15}{20}$	$= 7500\#$	$2500\#$	$10{,}000\#$

Case 4. P at the Center of Beam

$$H = 2500\,\frac{[24000 - 2875]}{32000 + 48000 - \dfrac{5\times(115)^2}{2}} = 1125\#$$

$$Q = K = \frac{2250\times 115 - 10{,}000\times 5}{40} = 5220\#$$

$$V = P/2 = 5000\#$$

Moments plotted and figured for Case 4:

$M^K_e = Hf = -1125\times 15 = -16{,}875'\#.$

$M^T_e = Hb - Ka = -1125\times 20 + 5220\times 5 = +3600'\#$

$M^K_b = Hb - Va = -1125\times 20 + 5000\times 5 = +2500'\#$

Max. Load $P = -1125\times 20 + 5000\times 10 = +27{,}500'\#$

Formulae for Vertical Loads

Case 1: *Load between Column and Brace*

$$H = P\,\frac{\left\{3bz(L-z) - \dfrac{a^2s + (z-a)^2s}{2a(n+1)}\right\}}{\left(4nb^2 + 6b^2L - \dfrac{as^2}{n+1}\right)}$$

$$K = \frac{Hs - Pa\,\dfrac{L-z}{L} - P\,\dfrac{(z-a)^2}{a^2}}{2a(n+1)}$$

$$Q = \frac{Hs - P\,\dfrac{za}{L}}{2a(n+1)}$$

Reverse K & Q if P is at opposite end.

Case 2: *Load between braces*

$$H = \frac{P\left\{3br(L-r) - \dfrac{a^2s}{2(n+1)}\right\}}{\left(4nb^2 + 6b^2L - \dfrac{as^2}{n+1}\right)}$$

$$Q = \frac{Hs - Pa\,\dfrac{L-r}{L}}{2a(n+1)} \qquad K = \frac{Hs - Pa\,\dfrac{r}{L}}{2a(n+1)}$$

$$Q - K = \frac{P\left(\dfrac{2r}{L} - 1\right)}{(2(n+1)}$$

where $s = (3bn + 3b - an)$ or $(3fn + 2an + 3b)$ as before

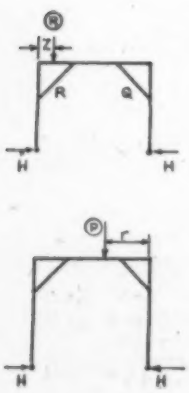
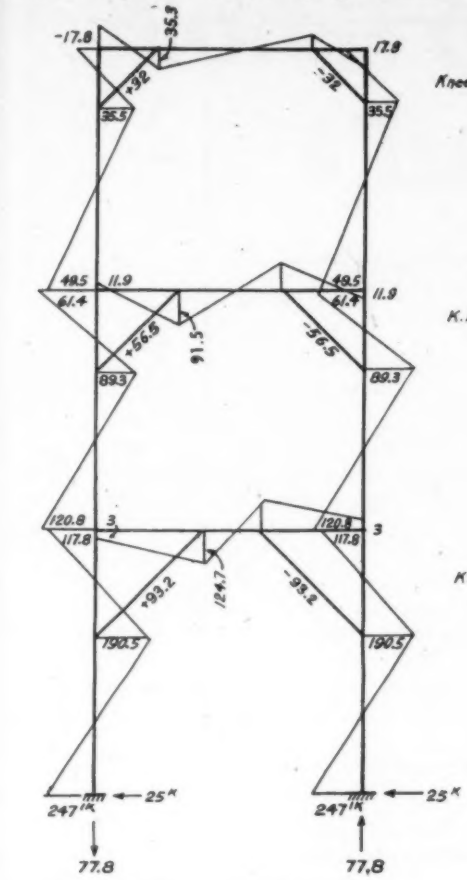


FIGURE 12

LOAD AT	K=	Q=	H=
Left Knee	$\dfrac{Hs - Pa\,\frac{a+g}{L}}{2a(n+1)}$	$\dfrac{Hs - P\,\frac{a^2}{L}}{2a(n+1)}$	$P\left\{\dfrac{3ab(a+g) - \frac{a^2s}{2(n+1)}}{4nb^2+6b^2L - \frac{as^2}{n+1}}\right\}$
Right Knee	$\dfrac{Hs - P\,\frac{a^2}{L}}{2a(n+1)}$	$\dfrac{Hs - Pa\,\frac{a+g}{L}}{2a(n+1)}$	$P\left\{\dfrac{3ab(L-a) - \frac{a^2s}{2(n+1)}}{4nb^2+6b^2L - \frac{as^2}{n+1}}\right\}$
Both Knees	$\dfrac{2\,Hs - Pa}{2a(n+1)}$	$\dfrac{2\,Hs - Pa}{2a(n+1)}$	$P\left\{\dfrac{3ab(L+g) - \frac{a^2s}{n+1}}{4nb^2+6b^2L - \frac{as^2}{n+1}}\right\}$
Center	$\dfrac{2\,Hs - Pa}{4a(n+1)}$	$\dfrac{2\,Hs - Pa}{4a(n+1)}$	$P\left\{\dfrac{\frac{1}{4}bL^2 - \frac{a^2s}{2(n+1)}}{(4nb^2+6b^2L - \frac{as^2}{n+1}}\right\}$

Stress Diagrams accomanying Ploblem (b)

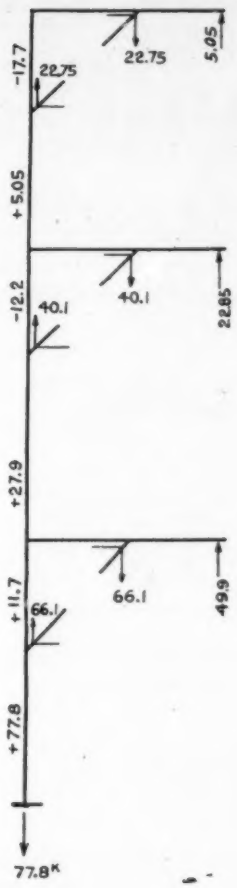


MOMENTS IN BENTS PLOTTED ABOVE
(ON TENSION SIDE OF MEMBERS)
MOMENTS IN FOOT KIPS

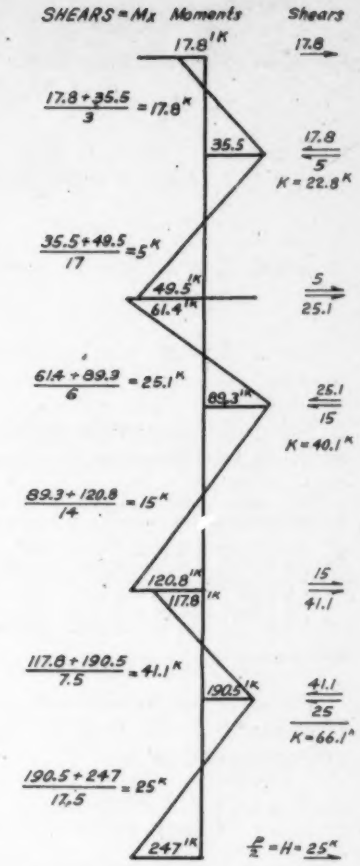
Knee Brace Stress = 32 K

K.B = 56.5 K

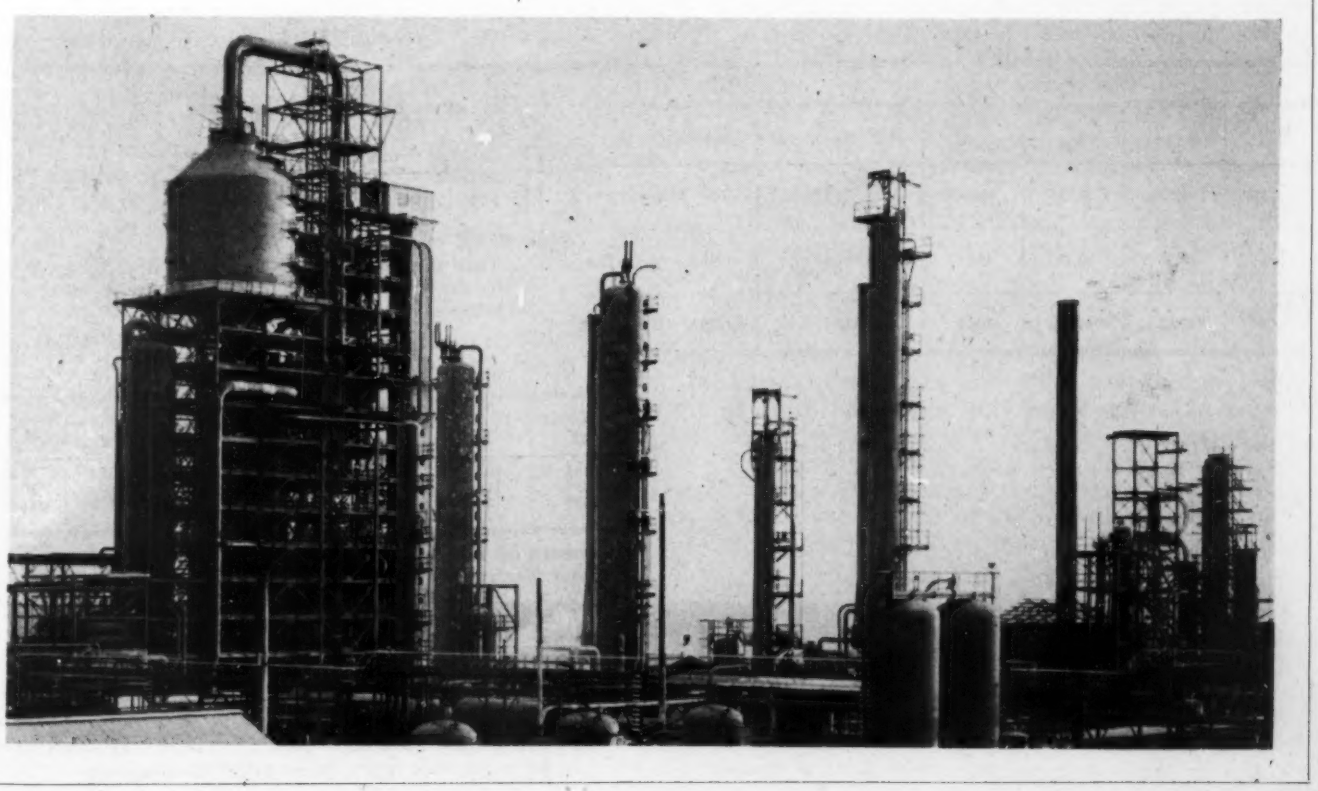
K.B = 93.2 K



VERTICAL COLUMN STRESSES
& KNEE BRACE COMPONENTS
ΣV Must Equal 0
Forces in Kips



HORIZONTAL SHEAR CHECK
M = Hor. Shear X Distance (ΣH = 0)
Shears in Kips



(B.) *Illustrative Problem of Multiple Tier Bent with Horizontal Forces.*

For Point of Inflection use charts

$$h_{o_3} = \frac{nL(3h-a)(h-a)+(L-2a)^2h}{2nL(3h-2a)+(L-2a)^2}$$

$n=1$ $L=20'$ $h=20'$ $a=3'$ { find $h_o = 49.5\%\ h = 9.9'$; then $b = h - h_o = 10.1'$

$n=2$ $L=20$ $h=20$ $a=6$ { find $h_o = 40.25\%\ h_o = 8.05'$; then $b = 11.95'$

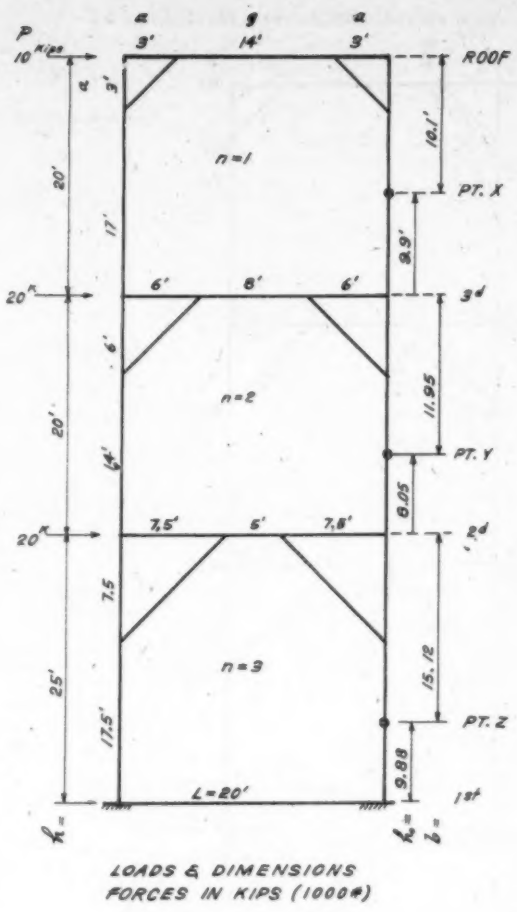
$n=3$ $L=20$ $h=25$ $a=7.5$ { find $h_o = 39.5\%\ h_o = 9.88'$; $b = 15.12'$

The following orderly tabulation is set up for the solution by formulae for those who dislike charts.

n	a	b	f	L	g	h_o	s=3fn+2an+3b	ΣP	$M^b_o = Ph_o/s$	FL.
1	3	10.1	7.1	20	14	9.9	21.3+ 6+30.3= 57.6	10	49.5′K	3rd
2	6	11.95	5.95	20	8	8.05	35.7+24+35.9= 95.6	30	120.8	2nd
3	7.5	15.12	7.62	20	5	9.88	68.6+45+45.4=159	50	247.0	1st

To solve for Kneebrace Components, the effects of Horizontal force P and 2 equal clockwise moments are combined thus:

$$K = \left\{\frac{s-2ab/L}{2a(n+1)}\right\} H + \left\{\frac{3-2a/L}{2a(n+1)}\right\} M = \frac{\Psi+\alpha}{\beta}$$



H=P/2	β=2a(n+1)	M^b_o	s	$2\frac{ab}{L}$	$s-\frac{2ab}{L}$	Ψ	$3-2a/L$	α	$K=\frac{\Psi+\alpha}{\beta}$	√2K
5K	12	0	57.6	$\frac{60.6}{20}=3.03$	54.6	273.0	3—.3=2.7	0	$\frac{273}{12}=22.75^K$	32
15	36	49.5	95.6	$\frac{12x11.95}{20}=7.17$	88.4	1326.0	3—.6=2.4	118.8	$\frac{1445}{36}=40.1^K$	56.5
25	60	120.8	159.0	$\frac{15x15.12}{20}=11.34$	147.7	3692.0	3—.75=2.25	271.8	$\frac{3964}{60}=66.1^K$	93.2

H=P/2	Hf	K-H	(K-H)a	M^T_C=Hf—(K-H)a	$M_B=-(M^B_C+M^T_C)$
5K	35.5′K	17.75K	53.3′K	— 17.8′K	—(0— 17.8)=17.8′K
15	89.25	25.10	150.6	— 61.4	—(49.5— 61.4)=11.9
25	190.5	41.10	308.3	—117.8	—(120.8—117.8)=—3.0

The knee brace stresses equal √2 (Component) where

{K acts in Tension
Q acts in Compression
H acts opposite to P

Moments at Knee-Brace—Beam Joint

This moment is due to Horizontal force P and to the 2 equal moments M clockwise at the column-beam joints.

$$M^K_B = Pbg/2L + Mg/L = (Pb+2M)\frac{g}{2L}$$

ΣP	b	Pb	2M	Pb+2M	s/2L	M^K_B
10K	10.1	101	0	101	.35	35.3′K
30K	11.95	358.5	99.0	457.5	.20	91.5
50K	15.12	756	241.6	997.56	.125	124.7′K

Moments of Knee-Brace-Column = Hf (see table)

Column Vertical Forces at the Point of Inflection

$$V_x = (10^K \times 10.1' = 101) \div 20 = 5.05^{K\,lps}$$

$$V_y = \frac{10\times 31.95 + 20\times 11.95}{20} = \frac{558.5}{20} = 27.9^{K\,lps}$$

$$V_z = \frac{10\times 55.12 + 20\times 50.24}{20} = \frac{1556}{20} = 77.8^{K\,lps}$$

$\Sigma M = 0$ at base

{$10\times 65 + 20\times 45 + 20\times 25 = 2050'^K$ M overturning
{$2\times 247'^K + 77.8\times 20 = 2050'^K$ M resisting

Non-Fouling Refinery Charge Stocks

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FOULING of heat exchangers operating on light, clean distillates is an aggravating problem frequently encountered in refineries.

This paper deals with the problem of fouling of heat exchangers due to deposits occurring when processing a clean distillate stock. The cause of the fouling from such stock, development of test methods to evaluate the heater-fouling tendency of an oil are discussed.

HEATING of oil is an integral step in most refining processes. Frequently, fouling of feed side of the heaters results from the formation of a carbonaceous deposit on the metallic surfaces. Fouling of heating units, especially tubular units such as heat exchangers or furnaces is particularly detrimental because of the difficulty of cleaning the units and the shutdowns occasioned by the necessity of cleaning.

Fouling of the feed side of tubular exchangers frequently occurs when charging naphthas or light gasoils. In particular, severe fouling has been encountered when charging California naphthas and gasoils to thermal reformers, catalytic reformers, and catalytic crackers. In these cases, the rate of fouling of the exchanger and furnace was not uniform even though inspections showed that the stocks were uniform in boiling range, chemical character, and free from sediment and suspended material. Continued testing of the stocks indicated that more severe fouling resulted from charging stocks that showed a high potential gum content. However, no accurate correlation could be made between the potential gum content and the fouling rate, and, consequently it was necessary to devise new tests.

From the fact that stocks having a high potential gum content gave the most severe fouling it appeared probable that the oxygen content of the stock was a factor in the rate of fouling. This hypothesis was supported by the history of stocks which had been processed since a review of the records showed that the most severe fouling occurred with feed stocks that had been in contact with air. Further investigation of the fouling problem followed along two lines; the development of a method of readily checking the fouling tendency of a feed stock, and the development of a method of removing the cause of fouling.

Checking Fouling Tendency

Several methods of checking the fouling tendency of feed stocks were devised, including a convenient test for the amount of oxygen dissolved in the oil and several qualitative methods of estimating the relative severity of fouling which would be obtained from various feed stocks.

Equipment used in determining the dissolved-oxygen content of the oil consisted of a flask equipped with a filling connection, a vapor line for removal of gas, and a thermometer well; a mercury bottle for evacuating the flask; and an Orsat apparatus for analyzing the gas. Determination of the amount of dissolved oxygen in the oil was carried out as follows: A 1-liter sample of the oil to be tested was placed in the flask and the flask was evacuated to 50 to 100 mm. of mercury by using the mercury bottle as a pump and pumping the gas released to the Orsat. Evacuations were carried out at room temperature until the gas evolved showed no appreciable oxygen. The oil was then slowly heated to about 100° to 150° F., depending on the volatility of the oil being tested, and the evacuations resumed. The gas evolved was collected in the Orsat and analyzed for oxygen. The weight-percent of oxygen evolved was then computed by means of the equation:

$$\frac{\text{Ml } O_2 \text{ evolved} \times 32 \times 100}{22{,}400 \times 1000 \times \text{Sp. G. of oil}} = \text{Wt. \% } O_2$$

This procedure has given satisfactory results for oils containing from 1 to 20 milliliters of dissolved oxygen per liter of oil.

The first procedure improvised for evaluation of the fouling tendency of an oil was the so-called "bomb" test. In this test, a 100-milliliter sample of oil was placed in an open centrifuge tube and the tube was placed in a stainless-steel bomb which contained an atmosphere of natural gas. The bomb was then sealed and purged with natural gas to insure removal of all traces of oxygen from the sealing gas. After placing in an oil bath, the bomb was heated to 425° F. and maintained at this temperature for three hours under the vapor pressure developed. The bomb was then removed from the bath, cooled, and the centrifuge tube of oil visually inspected. Stocks which fouled badly caused a dark precipitate in the bottom of the tube with the precipitate decreasing in quantity and the color of the tested stock improving as the quality of the stock, in regard to heater fouling tendency, improved.

The bomb test gave qualitative correlation with heater-fouling tendencies as it was possible to determine stocks which were very good or very poor. However, the graduation was not sharp enough to classify stocks in the middle of the scale. Accordingly a more sensitive test, the so-called "glass coil" test was devised.

Glass Coil Test

In the glass coil test, a coil containing 10 feet of ⅛-inch inside diameter glass tubing was immersed in an oil bath maintained at 525° F. Oil was circulated through the coil at a rate of 5 gallons per hour under a pressure of 35 psi. The test was continued for four hours after which the coil was removed from the bath, rinsed with a light solvent and dried. Fouling

Glass Coil Test of Fouling Tendency of Houdry Feed Stocks
Stock:
330-550 SCR; CCL No. 672

tendency of the oil was indicated by the extent of deposit in the glass coil.

Although this test was similar to the bomb test as regards visual estimation of the results, it was more satisfactory than the previous test because of the increased sensitivity. Thus, depth and extent of deposit in the glass tube changed more noticeably with a change in the quality of the charging stock than did the quality and type of deposit in the bomb test.

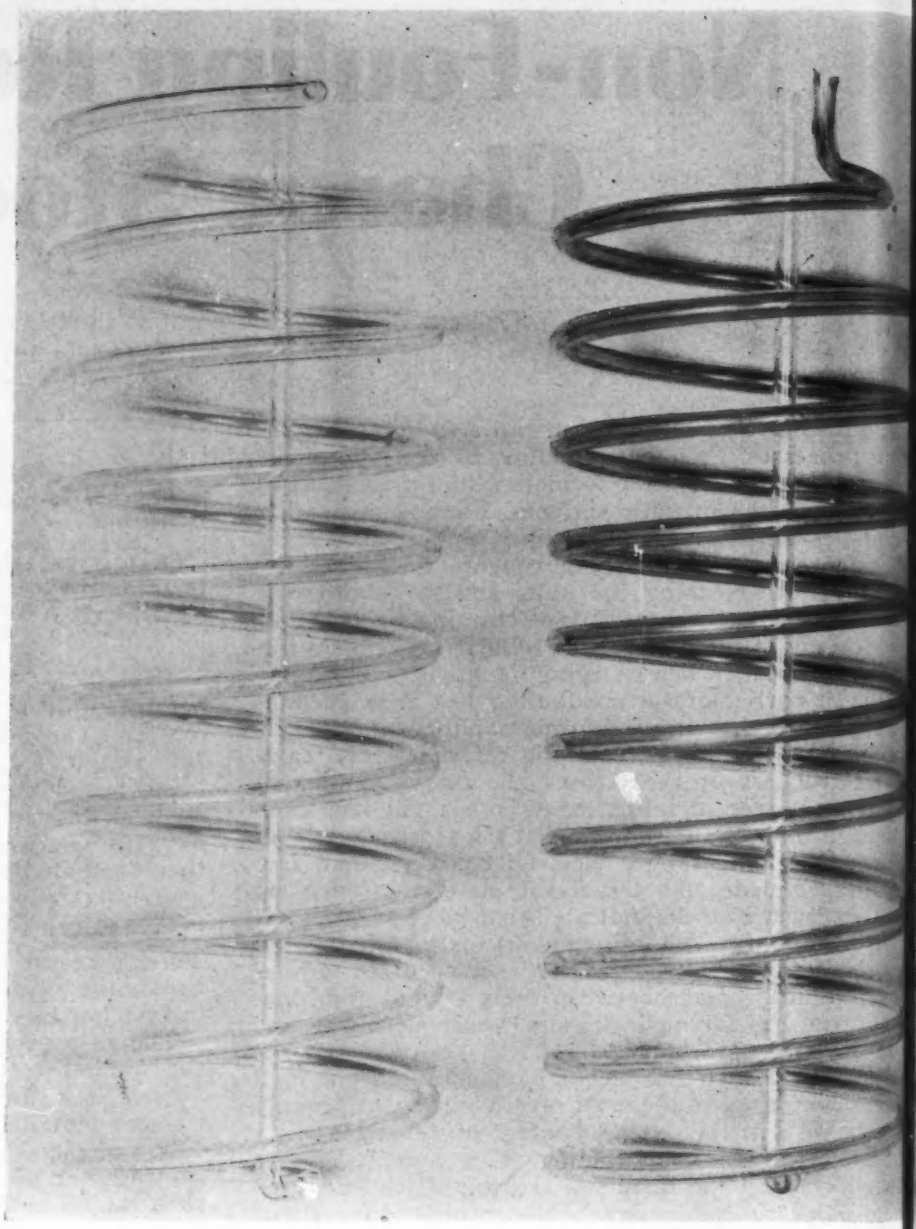
Removal of Oxygen

Along with the development of a satisfactory test for evaluating the heater fouling tendency of an oil, work on methods of improving the quality of the oil was undertaken. On the assumption that the fouling was primarily caused by the presence of dissolved oxygen in an otherwise clean and uncontaminated stock, improvement of the quality would be obtained by removal of the dissolved oxygen.

It was found that naphtha and gasoil in normal refinery handling could readily dissolve oxygen up to about 0.002 percent by weight, and tests showed that this amount of oxygen would cause severe fouling. Also, these hydrocarbons will continue to dissolve up to about 0.003 to 0.004 weight-percent oxygen when they are subjected to an oxygen-containing gas for a sufficient length of time or are agitated in the presence of an oxygen-containing gas. A hydrocarbon held in open tank storage for a few days, for example, will give a dissolved-oxygen content of about 0.0015 weight-percent, and a hydrocarbon shipped by tanker will usually give a dissolved-oxygen value of 0.003 to 0.004 weight-percent.

It will readily be seen, therefore, that, even with careful treatment during preliminary refinery operations, a hydrocarbon may easily pick up on the order of 0.002 weight-percent oxygen. In actual operating experience, using floating roof and gas-blanketed cone-roof tanks, the oil may still contain enough oxygen to cause undesirably severe heater fouling. It appeared, therefore, that the solution to the problem would be to remove the dissolved oxygen immediately before further processing rather than trying to prevent the oil from picking up oxygen.

Numerous methods of reducing the oxygen content of the oil are possible. Thus, topping the oil effectively removes oxygen from the bottoms; refluxing or topping the oil under vacuum is effective; stripping the oil with an oxygen-free gas or with steam results in oxygen removal; even rolling the oil in a storage tank with natural gas results in appreciable reduction of the oxygen content.



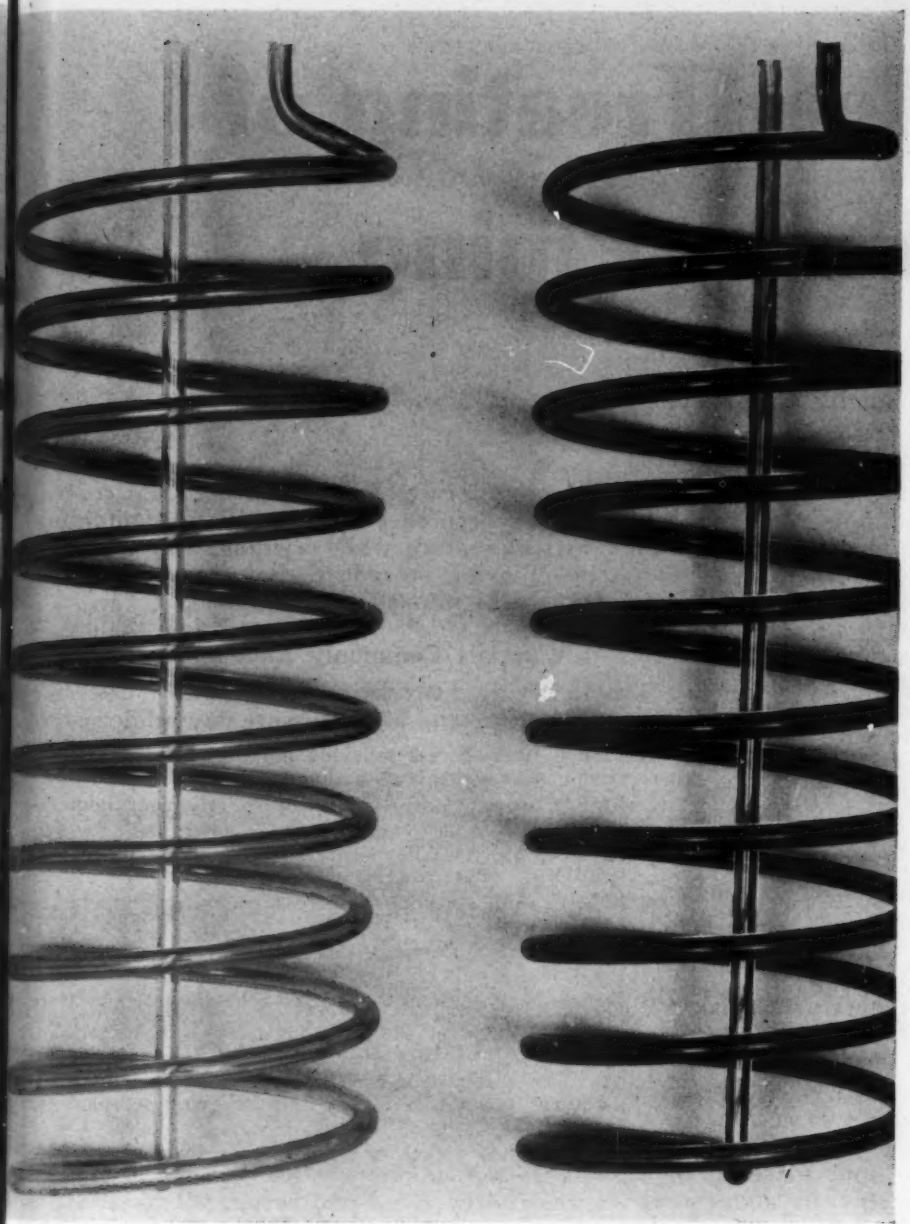
Clean Oil

TEST No. 10
Stripped with 120 cubic feet of natural gas per barrel in 42-inch glass column.

In a particular case occurring in one of the refineries, stripping with natural gas appeared to be the most practical and convenient way. It was found that stripping at elevated temperatures (150° to 250° F.) resulted in an appreciable increase in efficiency of stripping as compared to normal temperature stripping. However, care must be taken to keep the temperature below the temperature of fouling compound formation or generally below 300° F.

On Figure 1 are shown the results of glass-coil tests on an untreated catalytic cracking plant feed stock and on the same stock after stripping with natural gas. As a matter of comparison, the clean coil also is shown. It is obvious from the photographs that gas stripping greatly reduced the fouling tendency of the stock.

By comparison of plant heater fouling experience, extent of the deposit in the glass-coil test, and oxygen contents of the stocks, it was found that an



TEST No. 14
Stripped with 10 cubic feet of natural gas per barrel in 14-foot packed column.

TEST No. 6
Untreated barrel stock.

diameter by 30-foot column packed with ¾-inch carbon Raschig rings under 30 psig and at about 200° F. The oxygen content of the oil was reduced below 0.0004 weight-percent, and the glass-coil test showed no serious deposition. The gas-stripped oil then was passed through tubular heat exchangers and subsequently to a catalytic cracking unit. No fouling difficulty has been encountered.

In the second example, a California naphtha of about 45° API gravity was stripped with 20 to 25 cubic feet of natural gas per barrel of naphtha in an 8-foot diameter by 50-foot column packed with 20 bubble-cap trays. The temperature of the stripping unit was maintained at about 150° F. The oxygen content was reduced to a value below 0.0004 weight-percent. No significant deposits formed on the glass coil in a laboratory test nor in the tubular heat exchangers in commercial operation.

A feed stripper comprising a 6-foot diameter column packed with 24 feet of ¾-inch carbon Raschig rings was installed to remove dissolved oxygen from the gasoil feed to a catalytic cracking unit. The charge to the stripper consisted of a 36° API California gasoil of 330° F. to 600° F. boling range and normally contained .002 to .005 weight-percent dissolved oxygen.

TEST CONDITIONS:

Feed Rate	5 gal/hr.
Inlet Temperature	250°F.
Outlet Temperature	425°F.
Pressure	35 psi.
Test Duration	4 hours

Glass coil suspended in oil bath maintained at 525°F.

oil containing less than 0.001 weight-percent dissolved oxygen and otherwise free from gums or sediment would permit operation relatively free from fouling difficulties. This extent of deoxygenation was readily obtained by stripping with oxygen-free natural gas.

In Commercial Operation

Since realization of the effect of small amounts of dissolved oxygen on the fouling of tubular heaters and installation of gas strippers to correct this situation, fouling of heat exchangers has been reduced to a point where it no longer is a factor in length of runs. In several cases in which it was not practical to install a gas stripper, exchanger fouling has been greatly reduced by rolling storage tanks with natural gas immediately before feeding the stock. Following are several specific examples of removal of oxygen in commercial operation:

A California gasoil having an API gravity of 32.3° and a boiling range of 400° to 750° F., was stripped with 10 to 20 cubic feet of natural gas per barrel of oil. The stripping was carried out in a 5-foot

Stripping with 10 to 20 cubic feet of natural gas per barrel of feed reduced the oxygen content to below .0004 weight-percent. Before installation of the stripper, fouling of the heat exchanger tubes in zones where the gasoil temperatures were in the range of 350° F. to 450° F., raised the pressure drop through the exchangers to such an extent that it became necessary to reduce feed rate to the unit after only 700 hours of operation after cleanings. Since the feed stripper was put into continuous operation the exchangers have been in service for over a year without cleaning and fouling has been essentially negligible.

A California heavy naphtha of 40° API gravity used for thermal-reformer charge caused severe fouling of heat exchangers, limiting operation to 200-500 hours on stream. After reduction of the oxygen content of the charging stock by rolling the charging stock tanks with natural gas, plant operation showed great reduction of heat-exchanger and furnace-tube fouling and an increase of operating periods to 1500-2000 hours on stream.

Field Heat Treating of Refinery Piping

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EXTREMES in high and low temperatures, high pressures and corrosive operating conditions found in many modern refining processes have made it necessary to employ special alloys in the construction of units. Since most of the lines and vessels are fabricated by welding it has been necessary to develop techniques for annealing and stress-relieving field welds. Such heat treatment of vessels and prefabricated equipment usually is done in the furnaces of the fabricators. This article will deal only with some of the problems encountered in "on-the-job" heat treatment of welds; where furnaces are both unavailable and their use would be impractical.

Heat treatment of alloys is necessary for:

a. Stress relieving of stresses set up by mechanical strain or by the welding process;
b. Annealing to give the softest state of metal, and
c. Normalizing to give a more desirable grain structure.

There are other heat-treating procedures such as hardening, drawing and tempering which apply more properly to tools, machine parts or mechanical devices other than process piping.

In the case of carbon steel, annealing is accomplished by heating to about 100° F. above the "transformation temperature," holding one hour for each inch of thickness and cooling gradually to about 600° F. This gives the softest state of the metal, changing the grain structure and relieving mechanical stress.

Grain Structure Change

A change in grain structure occurs at the transformation temperature and the metal changes from the "ferritic" state to "austenitic." The difference between these two states is in the space lattice of the crystalographic structure of the metal. In the "ferritic" state the crystals are "body centered cubic." In the "austenitic" state the crystals are "face centered cubic." This change is accomplished by grain refinement and certain volume changes.

Transformation temperature varies with the composition of the metal, thus with 18 percent chromium, 8 percent nickel, sufficient alloying elements have been added to lower the crystalographic transformation temperature below room temperature, where in carbon steel this temperature is in the vicinity of 1450° F.

In stress relieving we stay below the crystalographic transformation or critical temperature (approximately 100° F.).

It is necessary to preheat cast steel before welding to prevent mechanical stress being set up during the welding process, as well as after the mass has cooled. It is customary to preheat larger castings, maintain a minimum temperature while welding, and complete the stress-relieving procedure after the welding has been completed without losing temperature.

Materials Commonly Encountered

The following materials commonly are used for high temperature and high pressure in a refinery.

1. Carbon steel—Stress relieving not ordinarily necessary, except in heavier plates or lines.
2. 4-6% Chrome, ½% Moly.—Stress relieving temperature 1350° F.
3. Carbon Moly. Alloy—Stress relieving temperature 1250° F.
4. 12% Chrome (castings)—Stress relieving temperature 1350° F.
5. Carbon Steel Castings—Stress relieving temperature 1200° F.
6. Carbon-Moly. Steel — Stress relieving temperature 1250° F.

For low temperature the following are used:

1. "T-5" (a special low-carbon steel) for operating temperatures down to —50°—Stress relieving temperature 1150° F.
2. 2½% to 3½% nickel for temperatures down to —150°—Stress relieving temperature 1100° F.
3. Austenitic alloy, and special copper and nickel alloys for temperatures to 300° F. As a general rule these alloys do not require stress relieving.

Heating Rate

General practice recommended by the API-ASME Code is a heating rate above 600° equivalent to 400° per hour, divided by the thickness in inches, with a maximum rate of 400° per hour. The cooling rate should be 500° per hour, divided by the thickness in inches, with a maximum rate of 500° per hour.

It is not the purpose of this discussion to recommend any procedure as far as temperature or rates of heating and cooling, soaking time, etc., are concerned. These should be set by the metallurgists, inspectors or engineers responsible for the installation, and we will limit ourselves to a description of some actual field setups to do these jobs.

Thermocouples

Old-time methods of heat treatment by sight and color are satisfactory for the common tool steels when used by the experienced blacksmith. More exact and reliable methods of temperature measurement are necessary for heat treatment of structural alloys, but, with proper setups satisfactory work can be performed by men with little experience. Chromel-

alumel thermocouples, connected to a continuous high-speed recorder, are recommended. The thermocouples may be peened into small holes drilled into the metal, or may be spot welded in place, provided the amount of weld metal holding the couple in place is kept to a minimum. Fish-spine insulators may be used but the use of salamander covered thermocouple wires eliminates the necessity of insulating the wires by hand.

The hot junction of the thermocouple should be placed immediately adacent to the weld, unless the weld itself is more than 1½ or 2 inches wide. For such large welds couples should be placed in the weld metal and adjacent both sides of the weld.

The high-speed recorder is recommended where more than four temperatures are controlled from one instrument.

Burners

The burners are made of ¾-inch pipe with 3/32-inch holes, spaced ¾-inch apart. These holes are drilled so the flame will impinge on the parent metal approximately 1-inch from the beginning of the weld. Of course, where the weld is very heavy it is necessary to use an additional burner to impinge directly on the weld metal.

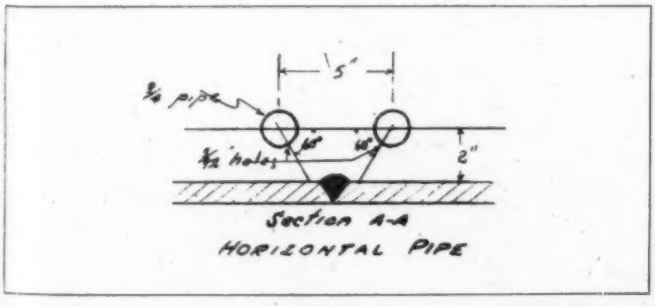

FIGURE 3

In the case of a horizontal pipe with a circumferential weld, the burners are spaced approximately 5 inches apart, with the holes drilled 30 degrees from the perpendicular. If the weld is around a vertical pipe the upper burner is drilled 30 degrees and the lower burner is drilled 15 degrees, to allow for the natural updraft of the flame.

Burner sections should not exceed 3 feet in length. This limitation is not due to lack of capacity of the burners, but because it is difficult to control temperature over a large area of metal with a single burner. Likewise, where burners are distributed around a horizontal pipe, the distribution should begin with one burner centered at the bottom, rather than to have the burner sections to end at the bottom, because of the natural upflow of heat.

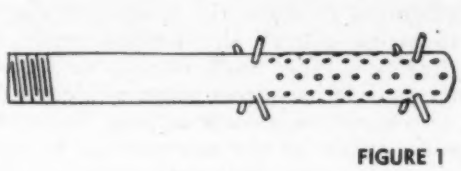

FIGURE 1

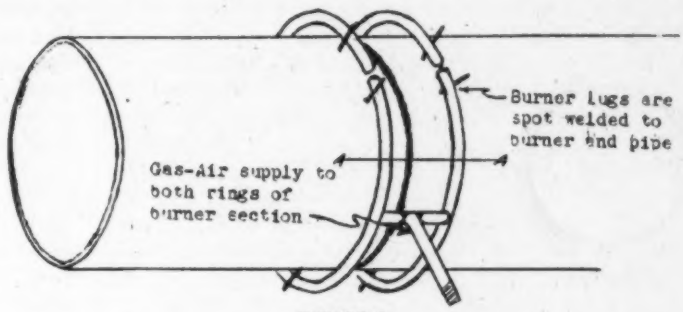

FIGURE 2

It is customary to attach a section of ½- or ¾-inch pipe to the burner shank. This serves as a mixing tube through which the air and gas are admitted. Plant residue or natural gas and compressed air may be used. Where a number of burners are set up for a single job, 1-inch pipe headers for both air and gas, with ¼-inch angle needle valves may be mounted below or beside the instrument. A semiflexible connection of ⅜-inch copper tubing is used to connect the air and gas from the header to the burners.

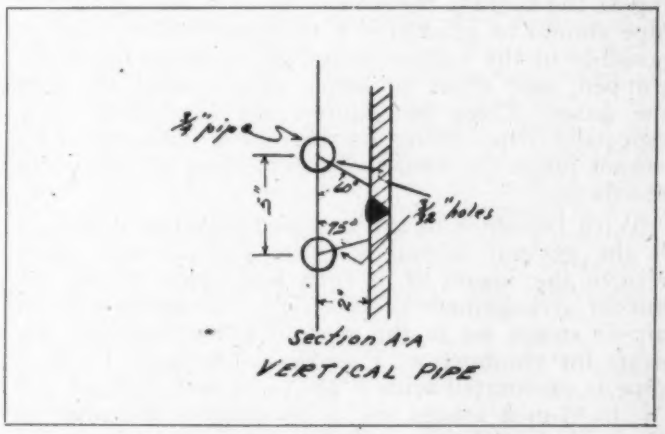

FIGURE 4

Protection of Work

Metal temperatures up to 1200° may be obtained by direct application of shop-made burners in the open. When higher temperatures are necessary it is advisable to "box" in the weld with fire brick or asbestos boards. In any case, it is best to shield the work from the weather either with tarpaulins or some type of housing. We have found that asbestos sheets

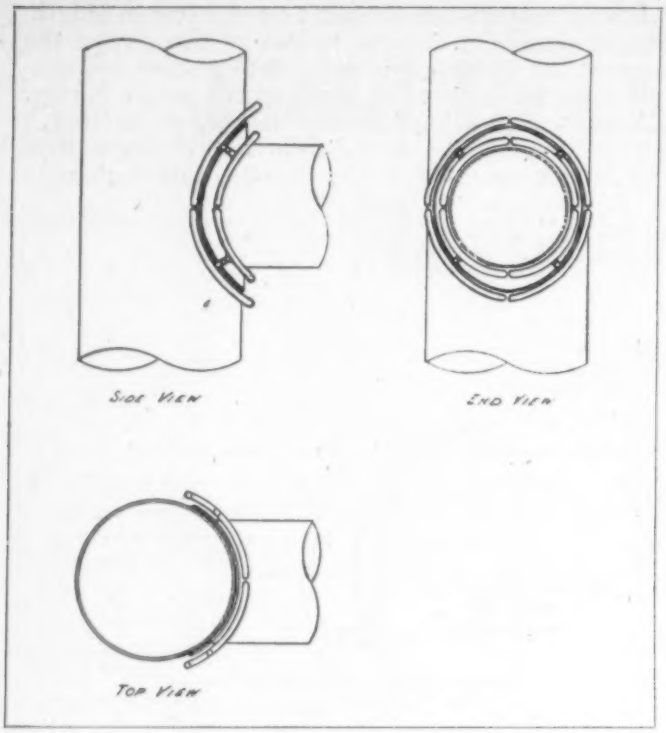

FIGURE 5

laced onto heavy wire matting make very satisfactory housing.

Of course, no shielding is necessary if the burners can be installed internally when stress relieving tubes or vessels. However, every precaution should be taken against trapping unburned gases in dead spaces when using internal burners.

A simple air jet may be used to syphon the gases from the highest point in a vessel or from the end of a tube opposite the burner. Where there is no opening at the highest point in a closed vessel, a suction pipe should be placed with the open end as near as possible to the highest point where gases could be trapped, and a jet or other device used to eject the gases. These precautions are very important, especially when using inexperienced operators who cannot judge the extent of combustion by observing the flame.

With reference to the attached sketches, Figure 1 is the general scheme used to preheat and stress relieve the inside of 10-inch lines and smaller. A burner arrangement of this type will necessitate an air or steam jet in the pipe to allow sufficient air draft for combustion. Usually a 1-inch or 1¼-inch pipe is perforated with 3/32- to ⅛-inch orifices and ⅜- to ½-inch braces are spot welded to the pipe, so the perforated burner will be centered in the pipe to be stress relieved.

Figure 2 shows the burner arrangement for preheating or stress relieving a large pipe weld. Sectional sketches Figures 3 and 4 will point out that when the burner is used to stress relieve a weld in a vertical plane the burner will be situated around the weld as shown in Figure 3. It is noted here that the flame propagation is at 60° angles from the horizontal plane. Figure 4 indicates the same type of stress relieve on a horizontal weld. The difference being noted in that the flame propagation from the lower ring will be at an increased angle, which is to allow for a natural up-draft.

Preheating to the desired welding temperatures in large lines is often accomplished with a double- or single-ring burner as is shown in Figure 2, with the exception that the orifices are located on the outermost diameter of the circular burner and the gas air supply is so arranged that suitable connections can be made to the inside of the ring. However, where it is necessary to stress relieve with the inside burner, the orifices are again directed at an angle toward the weld.

Figure 5 attempts to show the general burner arrangement to stress relieve the welded union of a nozzle on a line to a pipe. Such nozzles or lines are usually reinforced with a gusset plate welded to both pipes. It is, therefore, necessary to heat both pipes, welds and gusset plate at the same time. As shown by the end view, the innermost ring of the burner is located near the weld between the smaller pipe and the gusset plate, while the outermost ring is located just outside of the gusset-plate weld. It is desirable to allow the flame propogation from the innermost ring to be directed against the weld. The center line of the innermost pipe usually is placed at 2 inches from the smaller line and 2 inches from the gusset plate. Because of the larger curvature of the outermost ring and its distance away from the close structure, where heat is better retained, it is desirable to allow the flame propagation to strike the larger pipe at 1 inch from the weld. Practice at Baytown in vertical lines is to drill the orifices at 60° angles on the outermost ring at the bottom of the burner and allow these orifices to be pulled in gradually until, at the top of the outermost ring, the orifices will be directed at a 75° angle from the vertical plane. Where a very wide gusset plate is used on the line it is often desirable to introduce a third burner in the middle, such that the gusset plate will be heated throughout at an even tempertaure.

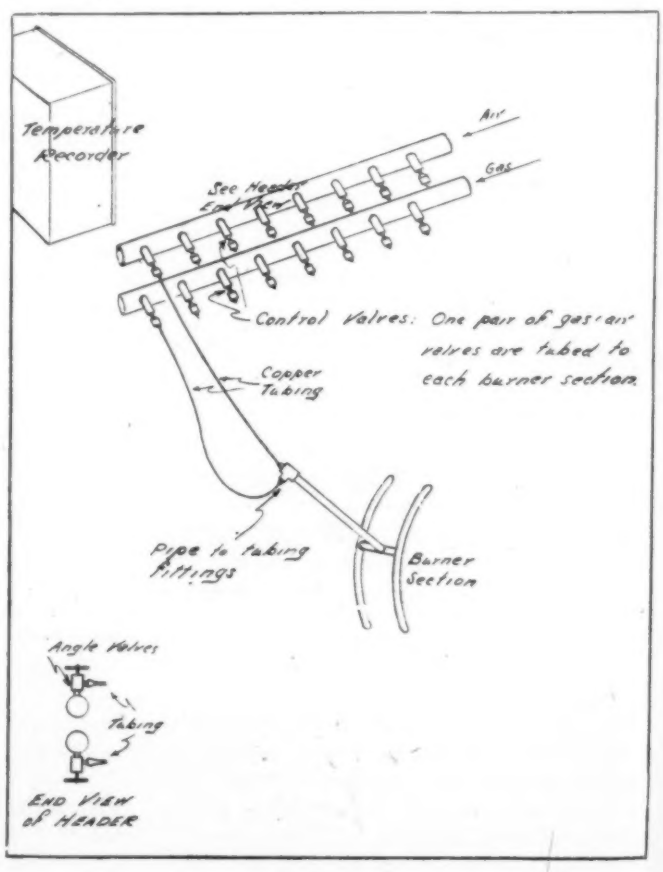

FIGURE 6

Water Content of Propane

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Research Department, Phillips Petroleum Company

THE liquid products of petroleum refining often are handled or stored under conditions such that they become saturated with water. The dissolved water will be, in some cases, an undesirable impurity and a knowledge of its concentration would be of value. The water content of liquefied petroleum hydrocarbons which are used as fuels and refrigerants is of particular importance. The n-butane-water system[2] has been studied in the three-phase region. One value is reported for liquid propane saturated with water at 80° F.[1] The experimental work reported here consists of a study of the propane-water system for the condition where two liquid phases and a vapor phase co-existed. The compositions of the propane-rich liquid phase and the vapor phase are reported for the temperature range 60 to 187° F. Equilibrium vaporization constant curves for water and weathering diagrams are presented for both the propane-water and n-butane-water systems.

Apparatus and Materials

The samples of equilibrium liquid and vapor were obtained from a cell placed in a constant-temperature, liquid-filled, agitated bath. As the samples were taken from the cell, they were passed through glass-wool traps before entering absorbers filled with magnesium perchlorate saturated with propane. The magnesium perchlorate quantitatively removed the water from the gas. After passing through the absorbers, the gas was again saturated with water before it entered the wet-test meter in order to prevent removal of water from the meter. When the absorbers were not in use, they were isolated from the system by means of stopcocks. Figure 1 shows a schematic diagram of the analytical train as used.

The temperature of the bath was thermostatically controlled and was measured by a mercury-in-glass thermometer graduated in 0.5° F. increments.

For temperatures below 140° F. the equilibrium cell consisted of a two-liter Lucite cylinder provided with an induction tube for obtaining liquid samples. Equilibrium was obtained by shaking the cylinder by hand.

For temperatures above 140° F. a steel cell of 750-cubic-centimeter capacity was used, equipped with an induction tube and suitable valves for drawing off samples.

The propane used was obtained from Phillips Petroleum Company and was of Pure Grade, with a purity of 99.9 mole-percent or better.

The anhydrous magnesium perchlorate used was of C. P. Grade sold by J. T. Baker Chemical Company under the trade name "Anhydrone."

Ordinary laboratory distilled water was used to saturate the propane.

Method

The charging operation consisted of adding 10 to 20 cubic centimeters of distilled water into the evacuated cell followed by the desired amount of propane. Before entering the cell, the propane was passed through an absorber filled with activated carbon to remove traces of sulfur compounds.

When starting a determination, the lines leading to the absorbers were evacuated then purged with a stream of propane. The rate of withdrawal of gas sample was at all times not more than 3 cubic feet per hour. The absorbers were weighed on an analytical balance and the gain in weight was taken as the weight of water in the propane sample.

Samples from the Lucite cell were obtained by cracking the valves and allowing the sample to escape due to its own pressure. In the case of vapor this would result in a continuous vaporization of liquid propane in the cell. To maintain the temperature constant and the vapor saturated with water, the rate of withdrawal of vapor sample was maintained

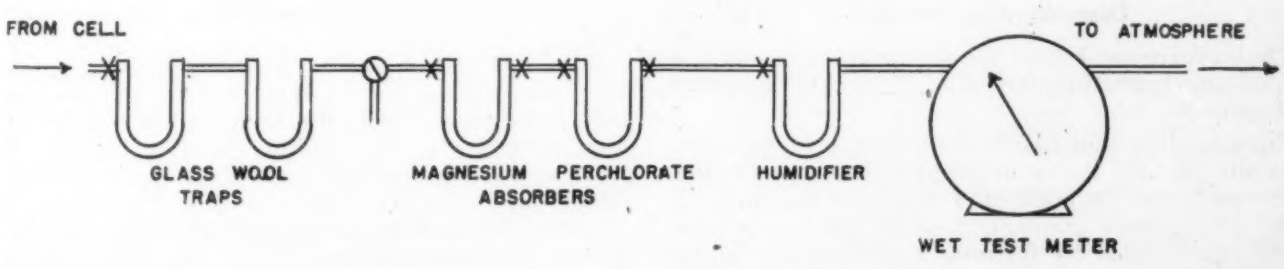

FIGURE 1
Analytical train.

Table 1

Summary of Experimental Results for Propane-Water System

LIQUID PHASE			VAPOR PHASE		
Temp. ° F.	Weight Percent Water	Mole Percent Water	Temp. ° F.	Weight Percent Water	Mole Percent Water
60	0.0110	0.0269	60	0.1334	0.3260
80	0.0192	0.0469	80	0.1694	0.4140
100	0.0279	0.0682	100	0.2126	0.5196
100	0.0305	0.0745	100	0.1847	0.4514
140	0.0642	0.1569	100	0.1768	0.4321
177	0.1923	0.4700	140	0.3311	0.8092
180	0.1881	0.4597	140	0.3465	0.8468
184	0.1976	0.4829	177	0.5134	1.2547
187	0.2209	0.5399	187	0.5862	1.4327

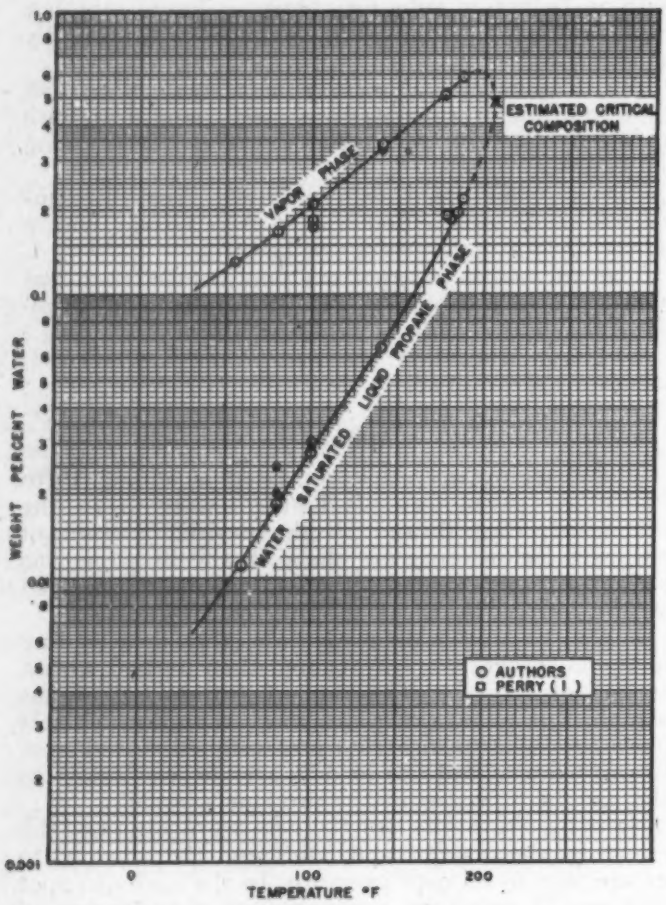

FIGURE 2

Propane-Water System.

at a low rate while thoroughly agitating the system.

The samples were obtained from the steel cell by constant pressure mercury displacement.

Discussion of Results

The experimental data for the propane-water system obtained are summarized in Table 1 and plotted in Figure 2.

Figure 3 is a plot of the equilibrium vaporization constant (K) for water in propane and in n-butane. The equilibrium vaporization constant for water is equal to its mole concentration in the equilibrium vapor (y) divided by its mole concentration in the equilibrium liquid (x). When the concentration of a component is very low such as water in propane or n-butane, the K constant computed using the concentrations expressed as weight percent is essentially the same as the value computed using mole concentrations. The K constants for water in propane were

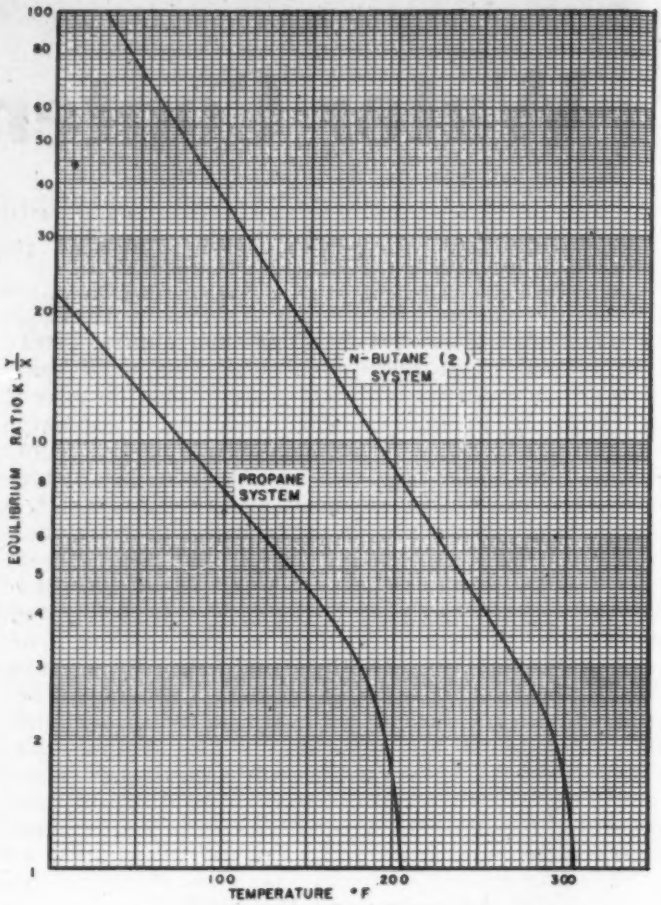

FIGURE 3

Equilibrium vaporization constants for water.

computed from the smooth curves of Figure 2 and are represented by the equation:

$$\text{Log } K = 1.3465 - 4.6475\,(10^{-3}t) - 10^{(-0.2196 + 0.0426644\,t)}$$

The K constants for water in n-butane were obtained from the data of Reamer et al[2] and are represented by the equation:

$$\text{Log } K = 2.1789 - 6.2208\,(10^{-3}t) - 10^{(-29.3816 + 0.07\text{[illegible]}t)}$$

Where t is the temperature in ° F.

Both of these equations are based on data for the condition where a water phase existed and for temperatures up to the critical temperatures where K is equal to unity.

Since Henry's law holds for very dilute solutions of solute in a solvent, such as water in propane or n-butane these equations are valid for water concentrations in the hydrocarbons below the saturation values.

As can be seen from Figure 3, the K constants for water in propane and in n-butane are greater than unity; and as a result, the hydrocarbons dehydrate upon weathering. The lower the temperature the greater the rate of dehydration since the K constant increases in value with decreasing temperature.

Figure 3 also demonstrates the fact that the equilibrium vaporization constant for water in n-butane is considerably greater than it is in propane.

A plot of the function $y = K_x$ at constant temperature on logarithmic paper would result in a straight line with a slope of unity and passing through the point $y = K$ at $x = 1$. The upper concentration limits of this family of curves is the locus of points

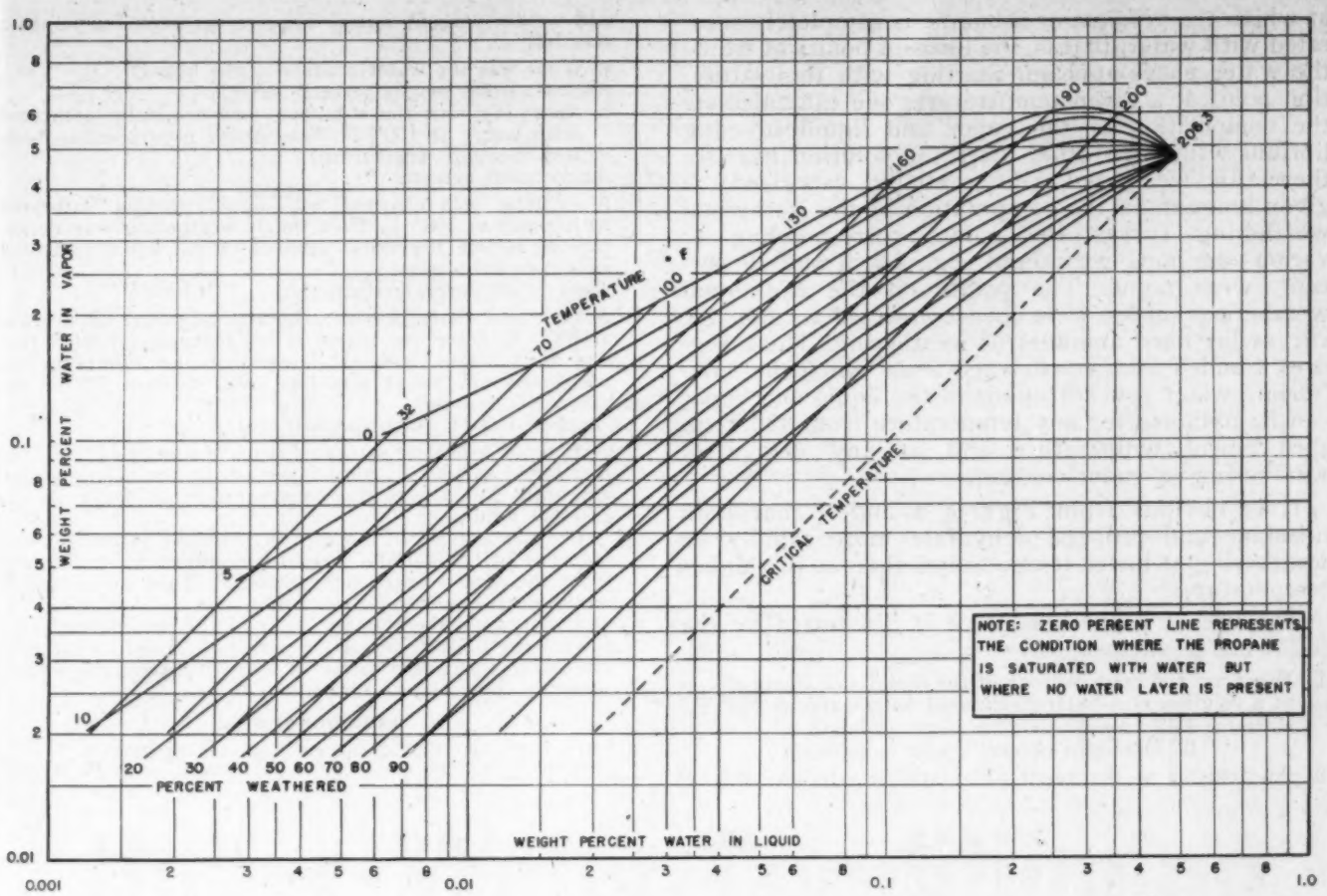

FIGURE 4
Weathering Chart for Propane-Water Mixtures.

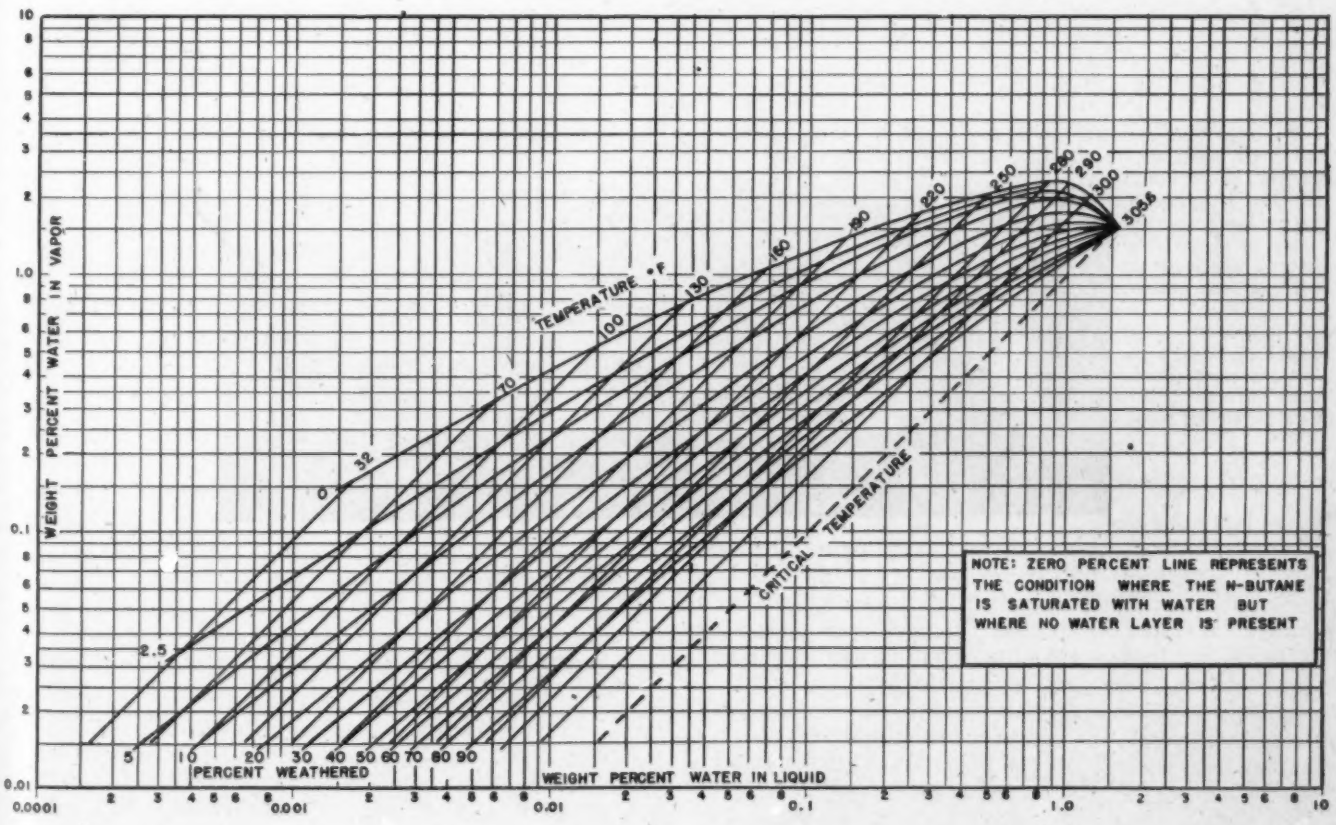

FIGURE 5
Weathering Chart for N-Butane-Water Mixtures.

at which the propane or n-butane is completely saturated with water, that is, the locus of points at which the water phase appears. Starting with this saturation point at a given temperature, one can calculate the composition of the vapor and liquid in equilibrium with each other after the solution has isothermally weathered (differentially vaporized) a given amount. In the computation of the isothermal weathering curves the points corresponding to various amounts weathered, e.g., 2.5, 5 and 10 percent, were noted. The points on the isothermal weathering curves were then connected to give the curves for fixed amounts of weathering. Thus, Figures 4 and 5 were constructed from which the equilibrium water concentrations in the liquid and vapor can be obtained for any temperature from 32° F. to the critical temperature and at any degree of weathering or water content.

It is obvious from Figures 4 and 5 that both n-butane and propane dehydrate more rapidly on weathering at lower temperatures than at the higher temperatures.

The use of Figures 4 and 5 is illustrated by the following problems:

1. What are the compositions of the liquid and vapor phases of a solution of n-butane saturated with water at 190° F.?
   Answer: 1.40 weight-percent water in vapor
   0.140 weight-percent water in liquid.
2. An analysis of the vapor of a tank of n-butane showed 0.18 weight percent water. The average tank temperature was 100° F.
   a. What was the water content of the liquid?
   Answer: 0.005 weight percent water.
   b. Assuming that the n-butane was originally saturated with water at 100° F., how much n-butane has been lost through weathering?
   Answer: 3.0 percent.
3. A cylinder was charged with liquid propane saturated with water at 100° F. How much weathering was necessary to reduce the water content of the liquid to 0.0144 weight-percent water?
   Answer: 10 percent weathering.
4. A tank was charged with n-butane saturated with water at 100° F. After one month a level gauge indicated that due to a vapor leak, 5 percent of the n-butane had weathered off. What was the water content of the remaining n-butane?
   Answer: 0.0024 weight-percent water.
5. A tank of n-butane saturated with water at 70° F. was weathered at 100° F. until 5 percent of the n-butane disappeared. What was the concentration of water in the residual n-butane?
   The concentration of water in n-butane saturated with water at 70° F. is 0.0061 weight-percent, which is obtained from the zero percent line at 70° F. This concentration would correspond to 2.5 percent
   and represents the starting point of the weathering. Following the 100° F. line to 7.5 percent (2.5 + 5) weathered one obtains a concentration of about 0.001 weight-percent water in the residual n-butane.

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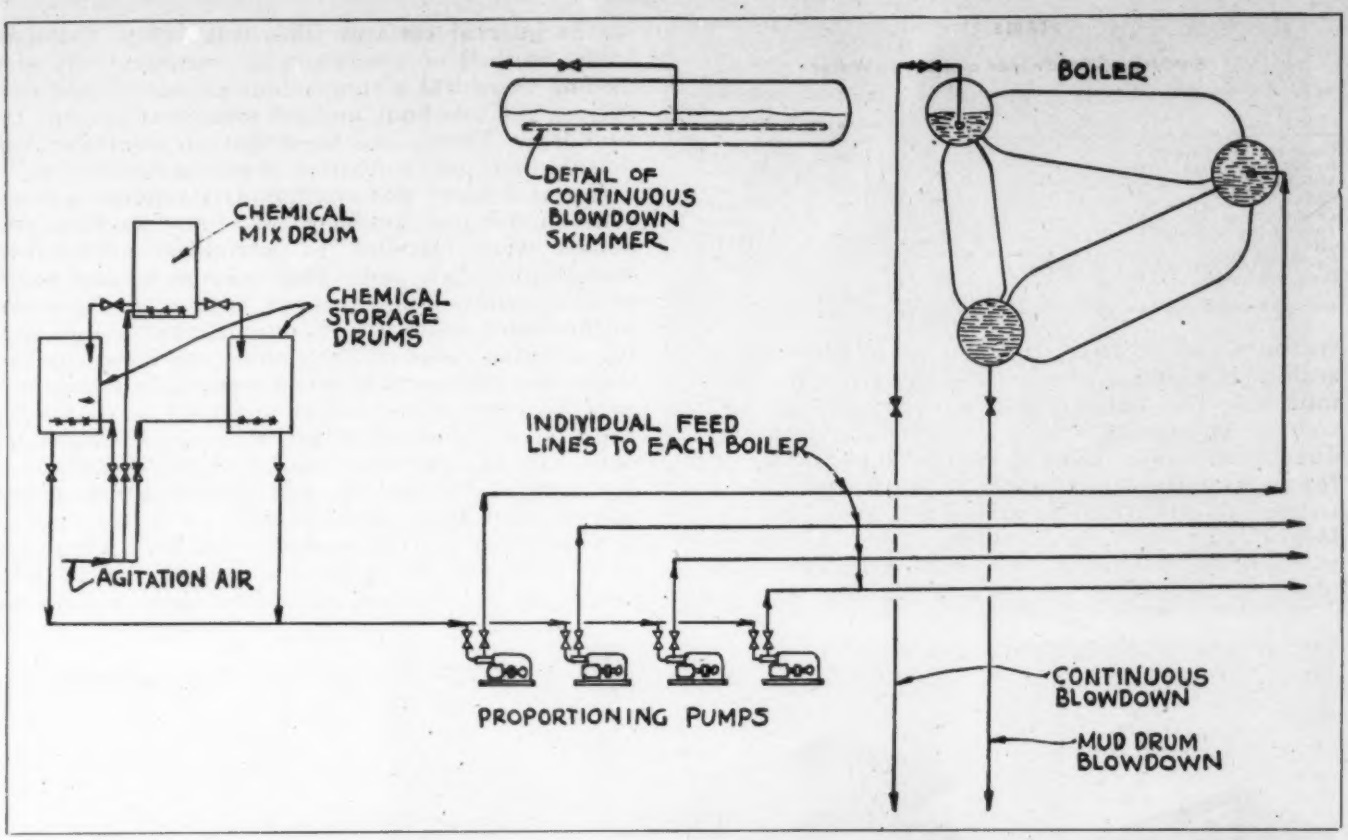
[2] Reamer, H. H., Olds, R. H., Sage, B. H., and Lacey, W. N., Ind. Eng. Chem. 36, 381 (1944).



Boiler-Water Conditioning At Talco Refinery

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THE Talco boiler plant consists of two water tube boilers rated at 378 horsepower each and two water tube boilers rated at 500 horsepower each. All four boilers are fired at 150-percent rating, totalling 2634 horsepower. The required makeup for this plant is 260,000 gallons daily of which 10 percent is condensate return. The 90 percent raw makeup is furnished from a 400-foot well. An analysis of the combined makeup is shown in Table 1.

Before corrective measures were taken, this boiler plant encountered the following problems:

1. Oxygen and CO_2 corrosion in steam lines.
2. Scale deposition on boiler internal surfaces.
3. High alkalinity, high total solids, foaming, priming and carryover of boiler solids into the steam lines.

The first problem was corrected by installing a vented deaerator on the feedwater line. By a counter-current flow the feedwater is scrubbed with exhaust steam. This arrangement has two advantages. It strips the dissolved oxygen and free CO_2 from the feedwater and also preheats the feedwater to 210° F.

The second problem of scale deposition took some time to conquer. The scale deposit that was forming in the boilers was a common scale known as calcium carbonate. The calcium in the feedwater is in the form of soluble calcium bicarbonate but upon entering the boiler is converted to insoluble calcium carbonate due to breakdown by heat.

$$Ca(HCO_3)_2 + \text{heat} \rightarrow CaCO_3 + HOH + CO_2$$

From Table 1 it is noticed that the feedwater has a total hardness of 17 parts per million. This means that each day about 37 pounds of calcium carbonate scale was being deposited in the boilers. After two or three months operation the tubes in the boilers became so well insulated by this scale it was necessary to fire nearly twice as hard to maintain the same steam capacity. After 90 days operation it was necessary to turbine this scale out of the tubes.
out of the tubes.

It was evident that either a water-softening unit would have to be installed or a means of internal

THE purpose of this article is to illustrate and explain the measures that have been taken to properly condition the boiler feedwater and boiler water at the Talco Asphalt & Refining Division, Mount Pleasant, Texas. It is not proposed to give the reader the impression that the following conditioning will be the solution to his boiler water problem. There is definitely no "cure-all" treatment that will work under every condition and with all types of waters. Each and every water problem must undergo an individual investigation.

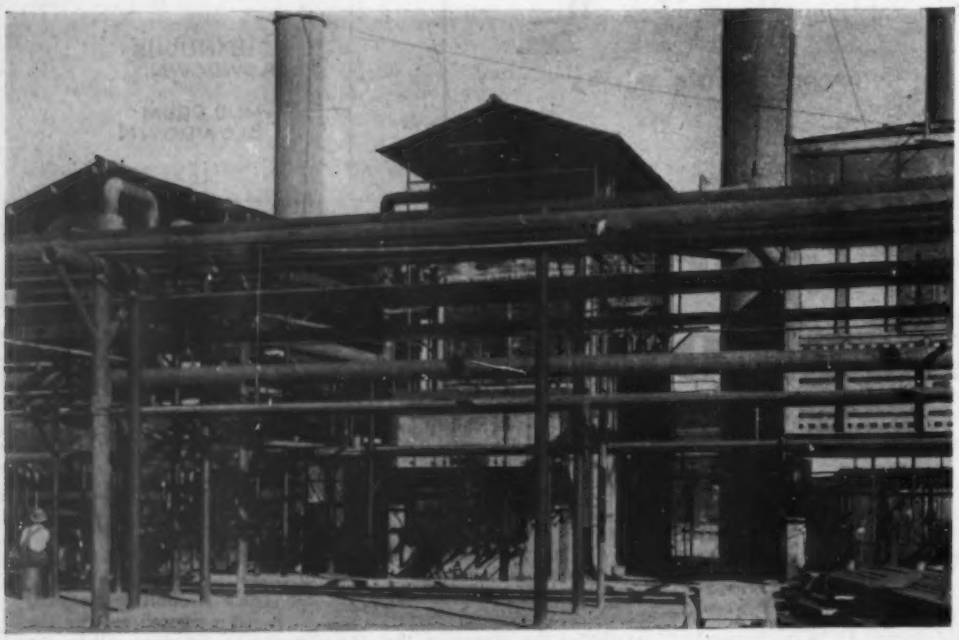
This investigation should include a chemical analysis of the feedwater to be used, types of boilers in service, percent rating the boilers are being fired, type of blowdown employed, raw makeup per day and condensate return per day. From this data a proper chemical treatment and plant procedure can be outlined to suit that individual problem.

TABLE 1

Analysis of Feedwater and Boiler Water

	Feedwater	Boiler
Hardness (as $CaCO_3$)	17 ppm	0
P—Alkalinity (as $CaCO_3$)	0	1342 ppm
M—Alkalinity (as $CaCO_3$)	208 ppm	1826 ppm
Chloride (as Cl)	100 ppm	1000 ppm
Phosphate (as PO_4)	0	55 ppm
Total Dissolved Solids	330 ppm	3400 ppm
pH	8.0	11.6
Cycles of Concentration	.....	10
Percent Blowdown	.....	10

treatment would have to be set up to form a softer scale that would not be so adherent to the hot boiler internals. The latter course was taken. Neutral disodium phosphate was selected to be introduced directly into the boiler drum. This phosphate salt reacts with the boiler water alkalinity to form trisodium phosphate. The trisodium phosphate thus formed reacts with the incoming calcium bicarbonate to form the flocculent precipitate, tricalcium phosphate



Front view of Talco's four boilers.

$$Na_2HPO_4 + NaOH \rightarrow Na_3PO_4 + HOH$$

$$2Na_3PO_4 + 3Ca(HCO_3)_2 \rightarrow 3Na_2CO_3 + Ca_3(PO_4)_2 + 3HOH + 3CO_2$$

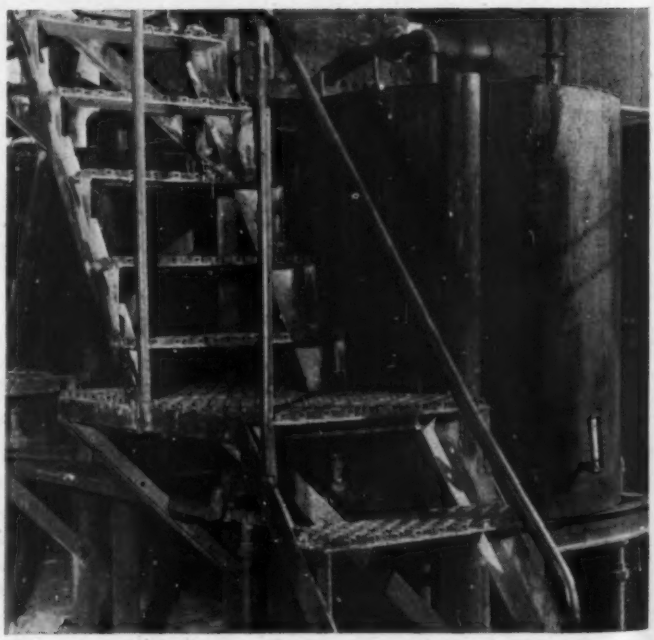
A sodium mannuronate type reactive colloid is used in adjunction with the disodium phosphate to maintain the tricalcium phosphate sludge in fluid form. This organic substance is used in equal portions by weight with the phosphate. It removes all residual concentrations of incrusting solids in the form of an organic gel. This gel, in turn, possesses the property of adsorbing the crystalline precipitates formed in the last reaction as well as other suspended solids, removing these from the system out the blowdown line. This prevents the interference of such solids with surface tension which aggravate a carryover condition.

It was first attempted to introduce these chemicals into the boilers by shot fashion. Every two hours a small blowcase was filled with a mixture of the phosphate and colloid solution and pressured into the boiler drum. After 90 days of treating the water in this fashion the boilers were brought down for inspection. There was still a noticeable amount of scale on the internal surfaces. This was due to the spasmodic method of administering treatment. By shot feeding there was a tremendous excess of treatment present for one hour and no treatment present the next hour. During the hour that no treatment was present there was formation of calcium carbonate.

It was evident that continuous treatment was the solution to this problem, so four proportioning pumps were installed to introduce continuously enough phosphate and colloid solution to each boiler so as to maintain an excess of 50 ppm phosphate ion in the boiler water. These pumps take suction from two solution tanks of 300 gallon capacity each. Two tanks are used so that when suction is taken from one, the other can be refilled and used for a standby. Eighty pounds of colloid and 80 pounds of disodium phosphate are put into solution with 250 gallons of hot water. This amount will fill one solution tank and will last about three days.

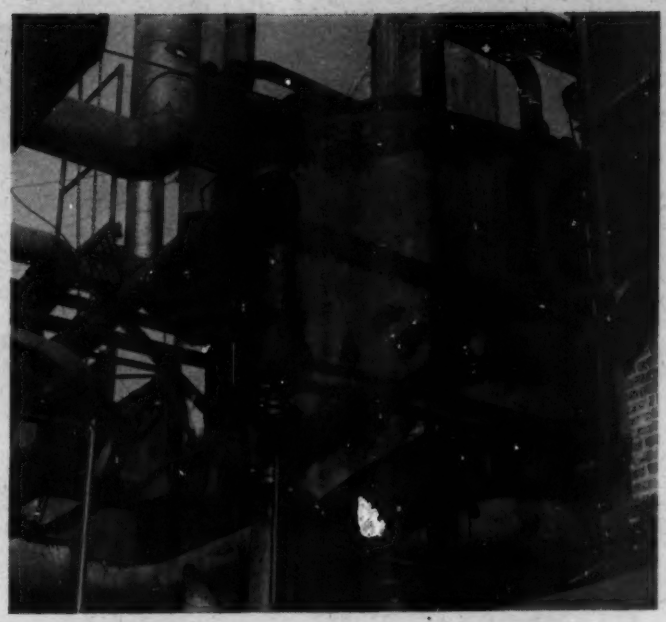
After three years operation it has been found that each boiler can be on the line for six months with practically no increase in firing. These boilers are

Chemical solution tanks.

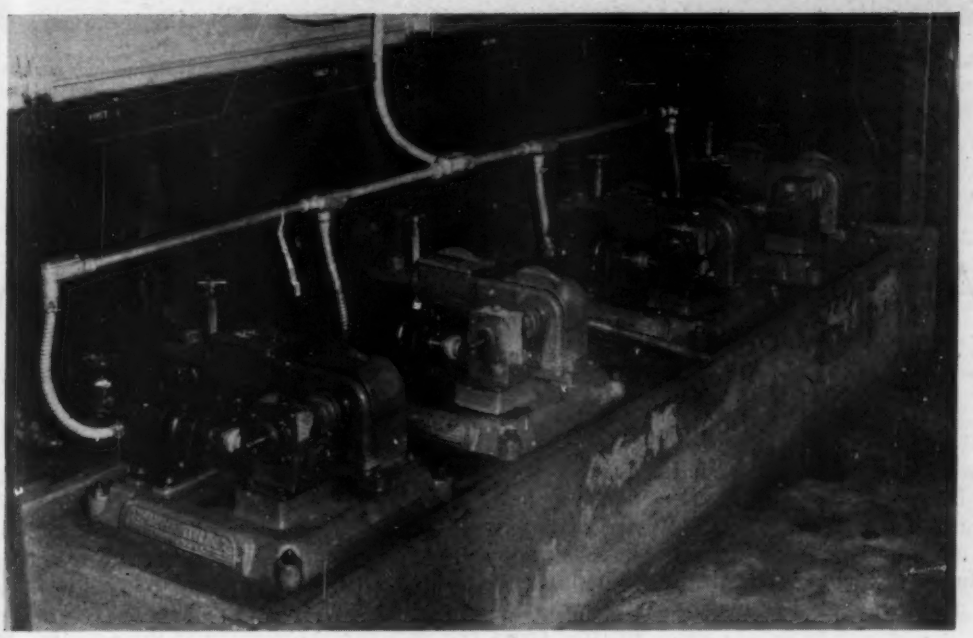


unheaded every six months and simply washed out to remove accumulated sludge deposits. The water tubes and drums have been so near free of scale that turbining has not been necessary. Continuous chemical treatment at this plant has cut shutdown time in half. A reduction of about one third has been realized in fuel consumption. One and one half times as much chemical was being used to shot feed than is being used continuously.

Problem 3, which consisted of high alkalinity, high solids, foaming, priming and carryover was overcome by the installation of a continuous blowdown line in each boiler. This consists of a ½-inch pipe running the entire length of the boiler drum and submerged about 4 inches below the water level. One-eighth-inch holes are drilled equidistant throughout the length of this pipe. Enough of these holes were drilled so that the total area of the holes is equal to the area of the ½-inch I.D. pipe. The ends of the ½-inch pipe are capped off. A control valve outside the drum regulates the blowdown rate of flow. At this plant it has been found that 10 percent continuous blowdown gives satisfactory operation.



Atmospheric deaerator.



Boiler-chemical proportioning pumps.

Hydrate alkalinity is formed in a boiler by the decomposition of sodium bicarbonate present in the feedwater.

$$2NaHCO_3 \xrightarrow{\text{heat}} Na_2CO_3 + HOH + CO_2$$

$$Na_2CO_3 + HOH \xrightarrow{\text{heat}} 2NaOH + CO_2$$

Since only water vapor is flashed off in the boiler the dissolved solids are left behind to continually build up. If no blowdown was employed these solids, including alkalinity, would built to an indefinite concentration. Excessive alkalinity that results in a pH of 12.0 or higher give cause for intercrystalline cracking or metal embrittlement. Excessive total solids cause bumping, foaming, priming and carryover into the steam line. Under certain conditions the bumping effect and shock from water hammer can be very dangerous.

Prior to the time that the continuous blowdown lines were installed, Talco had only used a periodic blowoff from the bottom drum or mud drum. This practice is all right but when heavy loads are maintained on the boilers the solids build up very rapidly between blows. With continuous blowdown used in conjunction with manual blowdown a constant alkalinity and total dissolved solids may be maintained at all times.

With continuous blowdown regulated at 10 percent the total alkalinity and total dissolved solids are constantly maintained within the ASME toleration of 3500 ppm maximum. The use of continuous blowdown makes it very easy to maintain the proper excess of chemical treatment in the boilers. Even though continuous blowdown is employed at the Talco boiler plant each boiler is given a manual blowdown from the mud drum every eight hours.

In conclusion, Talco's boiler plant is operating more efficiently with respect to oxygen corrosion, scale formation, foaming and priming. By deaeration practically all volatile gases are removed. By proper, continuous treatment scale formation is minimized and by employing continuous blowdown the boiler water solids are maintained within the tolerated limit, thus greatly reducing the chance of caustic embrittlement, foaming, priming and carryover.

Circulating system for handling 50,000 gallons per minute. Outdoor pump station and steam plant in rear.

Well Water Conservation

At Pan American Refining Corporation Texas City Refinery

PAUL HURD
Design Engineer

TREMENDOUS quantities of water are required by a petroleum refinery. In fact, to the uninitiated, the amount may appear fantastic. But for the operation of a refinery, water is as important as the oil being processed. It is necessary for process cooling, steam generation, sanitation, and other miscellaneous services.

The water supply for a refinery usually can be obtained from several sources. The availability and suitability determine the ultimate choice. Where the supply is unlimited, such as from a river, lake, or other body of water, the handling problem is considerably reduced and conservation is not too important except from the standpoint of reduced pumping costs. However, where this situation does not exist, cooling towers are necessary and in some instances other means of conservation become imperative.

The Texas City plant of the Pan American Refining Corporation obtains its water supply from wells. The initial determination was on the basis of economical availability and suitability. The sea water available from Galveston Bay, several miles from the refinery, was ruled out because of the economic factors. Even today when consideration is being given to a surface supply for augmenting the water obtained from the wells, Galveston Bay as a source of supply has been found undesirable, not only from the standpoint of economics but also in view of the problems incident to the use of salt water.

Limitations in sub-surface water availability and cost factors led to the initial and continued use of cooling towers at the Texas City refinery. These are of the atmospheric and mechanical types. In the latter category are both induced- and forced-draft designs. Expansion of the refinery and other local industrial growth greatly increased the water withdrawal from the sub-surface supply. This resulted in the lowering of individual well levels, thus increasing pump-head requirements and pumping costs. Trend projection indicated future decrease in well capacities when levels subsided sufficiently that well construction precluded further pump lowering. Therefore, it became economically desirable to supplement the cooling towers by additional conservation measures.

During the war years the accelerated expansion of industries in the locality again increased markedly the water-well pumpage. This has manifested itself in subsidence of the ground. In certain areas of the refinery, settlement in excess of two feet has been observed. This new problem, added to the economic factors, has prompted the refinery to adopt every reasonable conservation method so as to keep the water withdrawal from the ground at a minimum.

Underground Water History

The subterranean waters in the Texas City area generally are classified into four groups by their geological location: (1) water in the alluvial deposits; (2) the Beaumont clay formation; (3) the

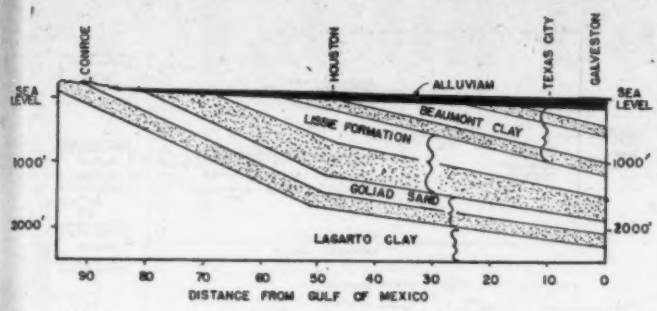


FIGURE 1

Generalized geologic section from Conroe southwestward to Galveston.

Lissie formation; and (4) the Goliad sands. Figure 1 shows these in an idealized geologic section. The quality of water in the alluvium is good but of no consequence because of the small quantity. Water from the upper sands of the Beaumont formation is comparatively low in total solids, chloride, and hardness; however, this source alone cannot supply the total plant need. The greatest withdrawals by the refinery are from the lower Beaumont or "Alto Loma" sand which yields water that is considerably higher in mineral content. The water obtainable from the lower formations is unsuited for most uses.

Withdrawals of ground water in the Texas City area began about 1893 but no accurate record of consumption was obtained until 1930. At that time the pumping rate was approximately 1.5 million gallons per day. Because of Texas City's rapid industrial growth, which included the construction of the Pan American Refinery, the rate rose to 23 million gallons per day by 1944, or approximately fifteen times that of 1930.

The tremendous increase in ground-water withdrawals (Figure 2) has resulted in a serious lowering in static well levels. Originally all the wells in Galveston County had sufficient artesian pressure to obtain free flow. In 1865 an artesian head of eight feet above the land surface was recorded for two wells in Texas City. Since then the artesian pressure has steadily declined because of the increased pumping rates until the static levels are now as much as 160 feet below the surface. Annual rates of decline have averaged from 8 to 14 feet since 1934. This situation has resulted in depletion of the low-capacity upper sands and necessitated increased withdrawals from the lower sands which contain water of higher solids content. Hence, the trend definitely is toward inferior water.

As the static levels in the wells declined, it became necessary at the refinery to lower pumps from time to time, adding stages and increasing motor horsepower to maintain design capacity. Also, various methods were adopted to effect conservation.

Plant Water System

As shown in Figure 3 the present water supply system consists of 10 wells varying in capacity from 600 to 1500 gallons per minute and in depth from 600 to 1000 feet. Water drawn from the shallow Beaumont sand is used primarily for supplying boiler-feed water because of its lower solids content. Each of the other wells discharges directly into the service water system which supplies the various other plant needs.

Where cooling towers proved impractical, well water supplying small process units (and other facilities) is discharged to the circulating systems for makeup in order to keep the well pumpage at a minimum consistent with economical operation. Until the well-water supply became critical, the conservation (or recovery system as it is called), was com-

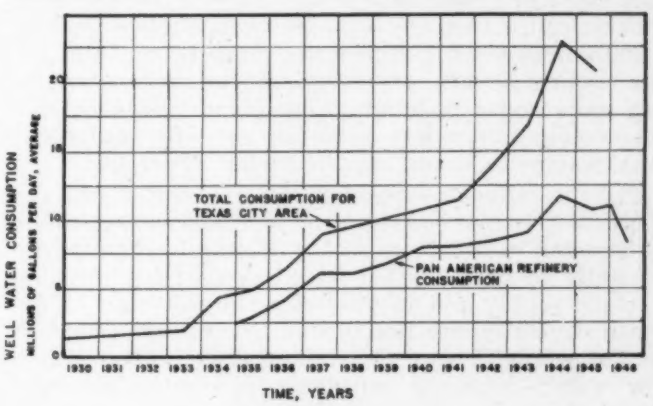

WELL WATER CONSUMPTION
MILLIONS OF GALLONS PER DAY, AVERAGE
TOTAL CONSUMPTION FOR TEXAS CITY AREA
PAN AMERICAN REFINERY CONSUMPTION
1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946
TIME, YEARS

FIGURE 2

Well water consumption.

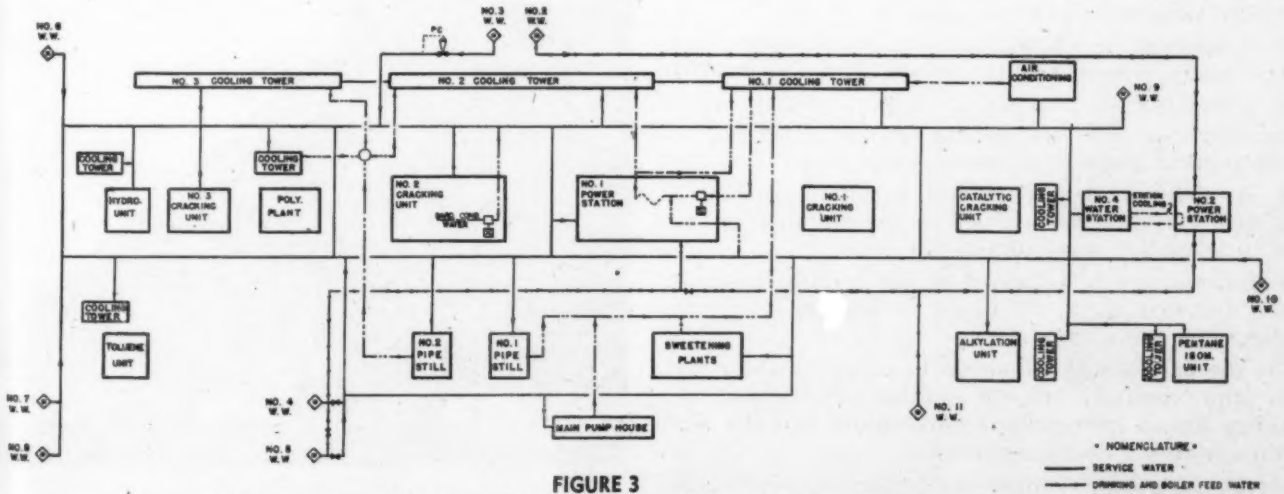


FIGURE 3

Schematic layout of service water, boiler feed water, and water conservation systems.

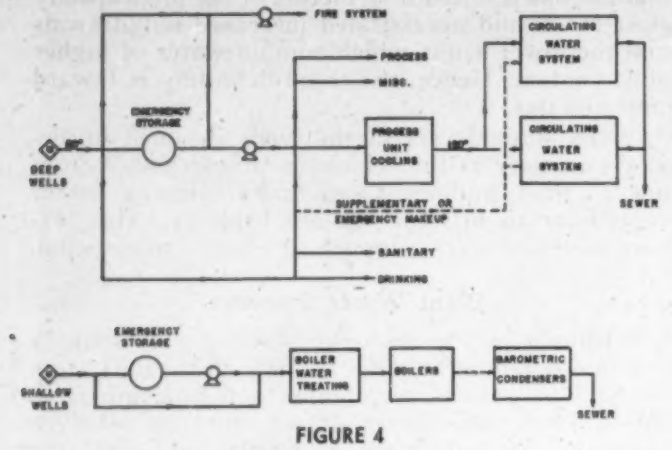


FIGURE 4
Partial conservation.

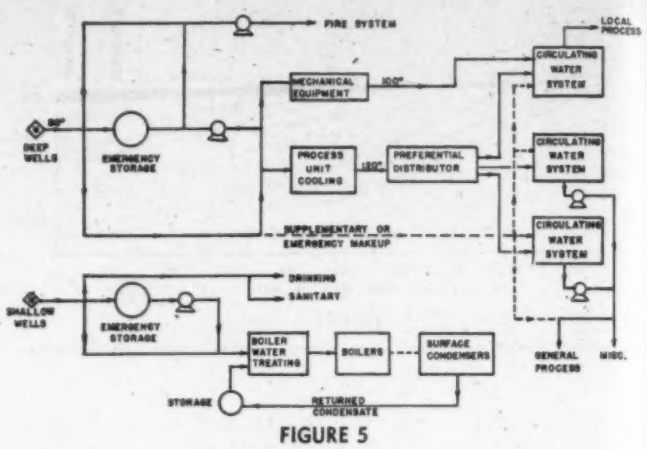


FIGURE 5
Full conservation.

paratively simple, as shown schematically in Figure 4. For example, because of the small heat load of the No. 1 Pipe Still, it was found economical to supply water directly from the water wells and then utilize this water as makeup to the circulating system operated in connection with a thermal cracking unit. This inexpensive installation resulted in a two-fold reduction in cost; it eliminated the necessity for a cooling tower and, because of the lower well-water temperature, permitted the installation of less cooling surface in the pipe still. When a second pipe still was added later, it was determined that its water requirement approximated the required makeup for the cooling towers serving two other thermal cracking units and a polymerization plant. Consequently, no cooling tower was provided and the equipment was designed for and supplied with well water.

As the refinery expanded and the water demand increased, further conservation facilities were installed to recover "usable" water for cooling-tower makeup in order to limit further withdrawals from the subsurface supply and to minimize the lowering of the static level. Where practicable, the normal overflow or "blowdown" from the cooling towers was utilized for water-washing petroleum products. Improved chemical treatment of cooling-tower circulating water permitted higher concentrations of solids, consequent reduced "blowdown" and reduced well-water pumpage. Concentration of the circulating water as compared to well water averages 3 to 1. The present chemical treatment is as follows:

1. A residual of 0.5 ppm of chlorine is maintained in the cooling tower basins to control algae growths.

2. A residual of 50 ppm of sodium dichromate is maintained in the circulating water to effect an 80-90 percent reduction in corrosion rates.

3. A sodium metaphosphate residual concentration of 2.5 ppm is maintained in the circulating system to minimize water-deposited scale.

4. Sulphuric acid is added to the cooling water in some systems as a stabilizer to further minimize water scale deposition.

By the beginning of 1946 the circulating water rate was approximately 160,000 gallons per minute, the makeup about 5900 gallons per minute and the well pumpage 8900 gallons per minute.

After the ground subsidence became apparent, further conservation measures were taken. In the power stations where well water was used previously for cooling, connections were made to the circulating systems of the adjacent operating units. This made possible the maximum utilization of the cooling towers. All usable well water not formerly recovered is now discharged into one of the cooling-tower basins and pumped into the service-water system for makeup to the other cooling towers and for additional process purposes. These various conservation measures are illustrated in Figure 5.

Since the first of the current year, the well pumpage has been reduced from 8900 to 6500 gallons per minute for comparable conditions of plant operation. The overall effect of all recovery measures has resulted in a saving of approximately 50 percent. Furthermore, the reduced well pumpage has tended to keep the level in the wells within a "pumpable" range and more recently has reduced the rate of ground subsidence. However, future static levels and ground subsidence cannot be treated on a plant basis but must be considered from the standpoint of the growth of the entire Texas City industrial area.

Preferential distributor for supplying "once-through" well water from a small process unit for makeup to three cooling towers. In the background —two atmospheric cooling towers for thermal cracking units.

Fat Oil Deethanization

A. M. WHISTLER
C. F. Braun & Company

OPERATING cost of a fat-oil deethanizer is higher than the usual type of plant. For practical purposes this extra cost is fuel cost. The fat-oil deethanizer does not fit certain cases. Where the primary purpose is recovery of propane or propylene, a special plant is required. Nor does it fit the case where a sidestream of propane is sufficient in quantity and quality, to supply the market. Operating cost, and to some extent first costs, make it unattractive. Where oil-rates are set by butane recovery, and a good market for propane exists—the fat-oil deethanizer has excellent possibilities.

IN AN absorption plant, fat oil leaves the bottom of the absorber with considerable amounts of methane and ethane. The absorption of these two gases is not from choice. Far better, could they be excluded in the absorption process. They are not wanted as products. And worst of all, they give trouble further on in separating out the desirable fractions.

Several methods have been used to rid the fat oil of all, or even a part, of these two constituents. The commonest method is so-called flashing into a drum at lower pressure. This is really a one-step fractionation. It is useful, but it has the disadvantage of every single-step fractionation: poor separation.

About 15 years ago, so-called fractionating-absorbers were tried. Two or three trays were added below the gas inlet of the absorber. A small steam coil was inserted into the fat oil at the bottom. No real gain resulted. Reboiling was too small for any substantial removal of methane and ethane.

Several years ago, propylene became valuable in certain petroleum-chemical plants. One of the large oil companies built an absorption plant for high recovery of propylene. It built a fat-oil fractionator for removal of all the methane. About half the ethane was removed also, without undue loss of propylene. All this was based on careful paper work before construction.

During the preliminary process work on a plant built about a year ago, the question was voiced, Can the ethane also be substantially removed from fat oil without too much loss of propane? The answer required a lot of tiresome paper work. But the paper work showed the idea to be practical.

Guarantees quoted were as follows. Propane retention, 70 to 80 percent of that absorbed in the main absorber. Propane purity 90 to 95 mol percent. Offhand, there seems no point in quoting a range. The lower figures of 70 percent retention and 90 percent purity are all that had to be met. But the higher figures were useful. They indicated what the plant would probably do.

Absorber Operation

Figure 1 is a simple picture of the flow. The main absorber operates like all absorbers. In it, over 95 percent of the total butanes are absorbed, and over 60 percent of the propane. The fat oil then goes to the middle of the deethanizer. Think of the fat-oil deethanizer as a fractionator. It has reflux. And it

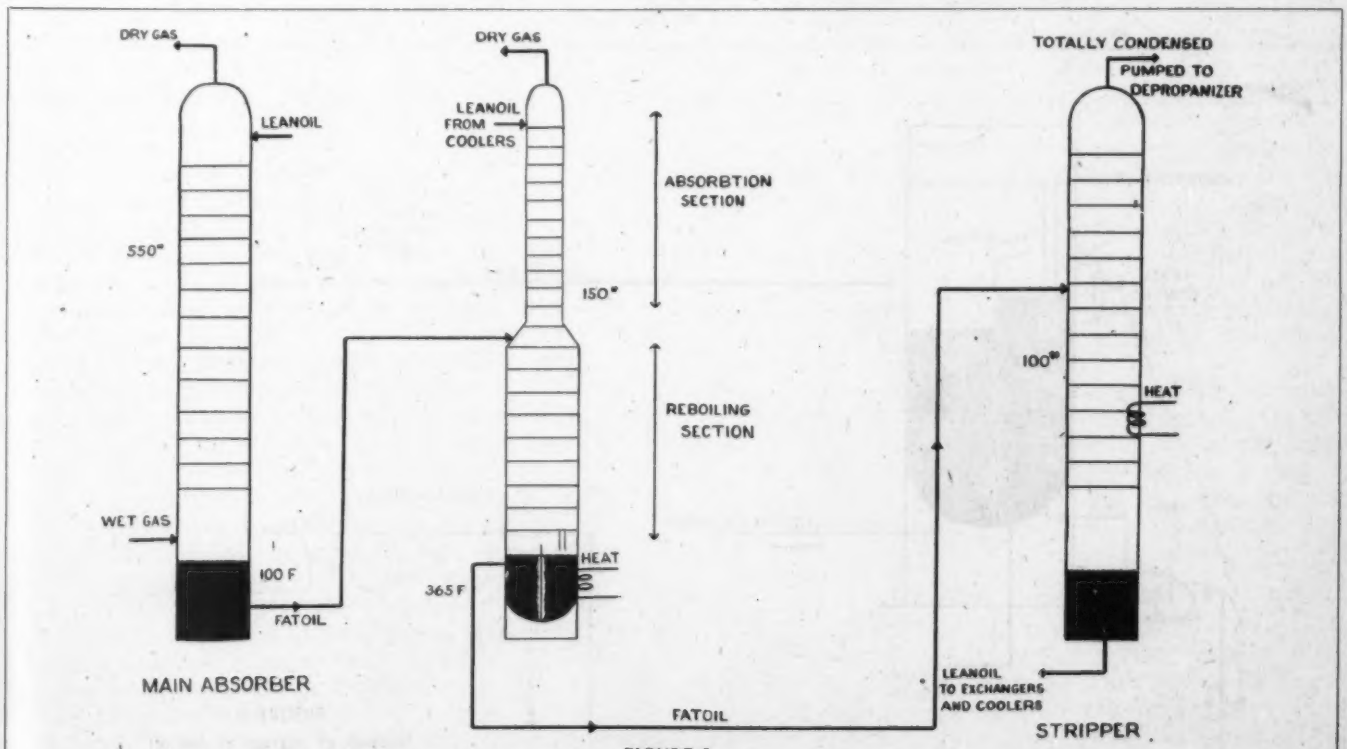


FIGURE 1
Simplified flow of Plant A with far oil deethanizer.

TABLE 1
Plant A—Acceptance Test Plant Balance

	WET GAS TO PLANT			VAPOR STREAMS DRY GAS FROM ABSORBER				Percent Recovery in Main Absorber	DRY GAS FROM DEETHANIZER			
	Mol Percent	Gal./ MSCF	MSCF/ 24 Hour	Gal./ 24 Hour	Mol Percent	Gal./ MSCF	MSCF/ 24 Hour	Gal./ 24 Hour		Mol Percent	Gal./ MSCF	MSCF/ 24 Hour	Gal./ 24 Hour
CO_2	0.60	.....	119	.....	0.60	.....	100	.....	....	1.00	.....	13	.....
H_2O	.....	.....	.....	.....	.....	.....	.....	.....	....	0.42	.....	6	.....
C_1	82.81	.....	16,376	.....	89.17	.....	14,800	.....	....	56.60	.....	759	.....
C_2	8.92	.....	1,766	.....	7.89	.....	1,311	.....	....	30.05	.....	403	.....
C_3	4.92	1.350	974	26,680	2.26	0.620	375	10,300	61.5	11.51	3.159	154	4,230
IC_4	0.68	0.222	135	4,395	0.03	0.010	5	166	96.1	0.30	0.100	4	134
NC_4	1.20	0.378	248	7,480	0.03	0.010	5	166	97.8	0.10	0.032	1	43
IC_5	0.26	0.095	51	1,880	0.02	0.009	4	149	97.9	0.02	0.010	.....	13
NC_5	0.20	0.072	40	1,425	.....	.....	.....	.....		.....	.....	.....	.....
C_6+	0.41	0.189	81	3,740	.....	.....	.....	.....		.....	.....	.....	.....
	100.00	2.306	19,790	45,600	100.0	0.649	16,600	10,781	....	100.0	3.301	1,340	4,420

Liquid Streams

	DEPROPANIZER OVERHEAD			DEPROPANIZER BOTTOMS		
	Mol Percent	Liquid Percent	Gal./ 24 Hour	Mol Percent	Liquid Percent	Gal./ 24 Hour
C_1	Trace	Trace	....	.....	.....	.....
C_2	0.30	0.26	31	.....	.....	.....
C_3	99.52	99.52	11,842	1.9	1.52	280
IC_4	0.18	0.22	26	23.3	22.38	4,140
NC_4	....	....	....	42.2	38.94	7,200
C_5+	....	....	....	32.6	37.16	6,880
	100.00	100.00	11,899*	100.0	100.00	18,500†

Material Balance

TOTAL OUTLET STREAMS			
	MSCF/ 24 Hour	Gal./ 24 Hour	Outlet/ Wet-Gas
C_1	15,559	.....	0.951
C_2	1,714	.....	0.971
C_3	.....	26,652	0.999
IC_4	.....	4,466	1.016
NC_4	.....	7,409	0.991
C_5+	.....	7,042	1.000

* Wet-gas less absorber dry-gas, deethanizer dry-gas, and depropanizer bottoms. † Based on production from 1 pm to 3 pm.

Recovery

	PROPANE	BUTANES	PENTANES PLUS
Based on Wet Gas Less Losses	Absorbed..... 16,380 Gal./24 Hr. Losses: C_2 Overhead 4230 C_4 Bottoms... 280 4,510 Percent Loss..... 27.6 Percent Recovery..... 72.4	Wet Gas..... 11,875 Gal/24 Hr. Losses: C_1 Dry Gas.... 332 C_2 Dry Gas.. 177 C_4 Overhead 26 535 Percent Loss..... 4.5 Percent Recovery..... 95.5[1]	Wet Gas..... 7,045 Gal./24 Hr. Losses: C_1 Overhead. 149 C_2 Overhead. 13 162 Percent Loss..... 2.3 Percent Recovery..... 97.7
Based on Liquid Products	Based on Propane in Fat Oil.....	Wet Gas..... 11,875 Gal./24 Hr. Production..... 11,340 Percent Recovery..... 95.6[2]	Wet Gas..... 7,045 Gal./24 Hr. Production..... 6,880 Percent Recovery..... 97.7
Contract	Depropanizer Overhead to contain not less than 70 percent of the propane absorbed in the Main Absorber. Overhead to be not less than 90 percent pure Propane.	Depropanizer Bottoms to contain not less than 95 percent of the total Butanes in the Wet Gas. [1] IC_4 93.2, NC_4 97.2 [2] IC_4 94.3, NC_4 96.3	Not Specified.

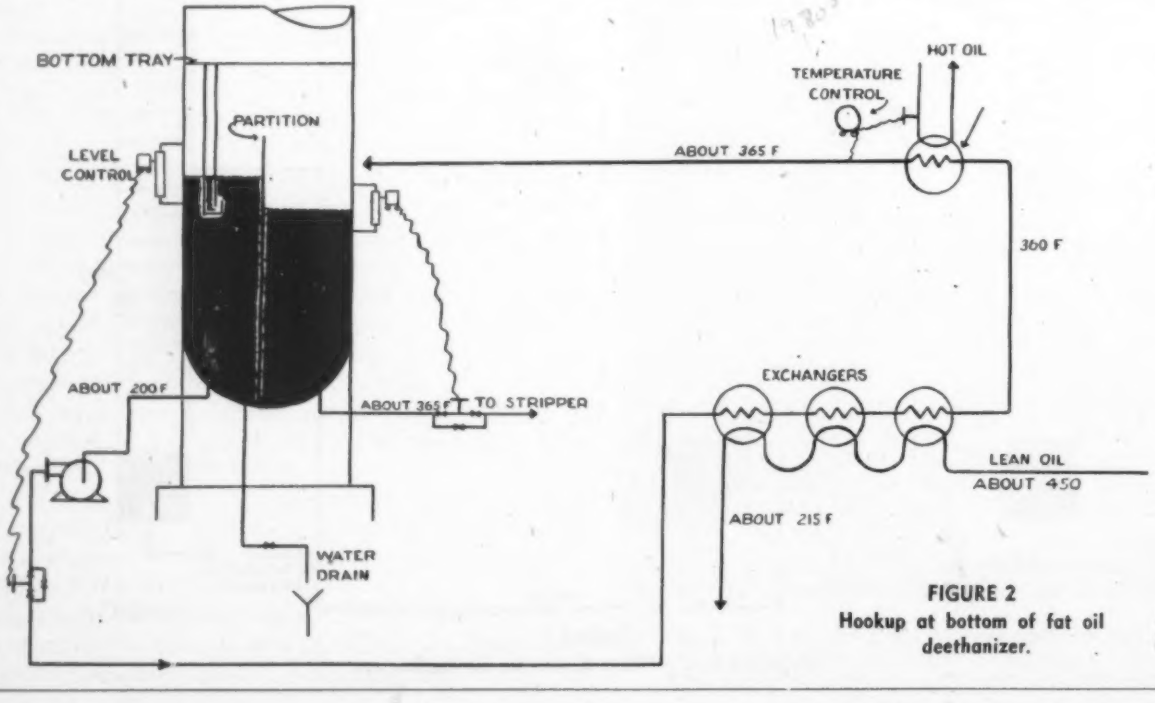


FIGURE 2
Hookup at bottom of fat oil deethanizer.

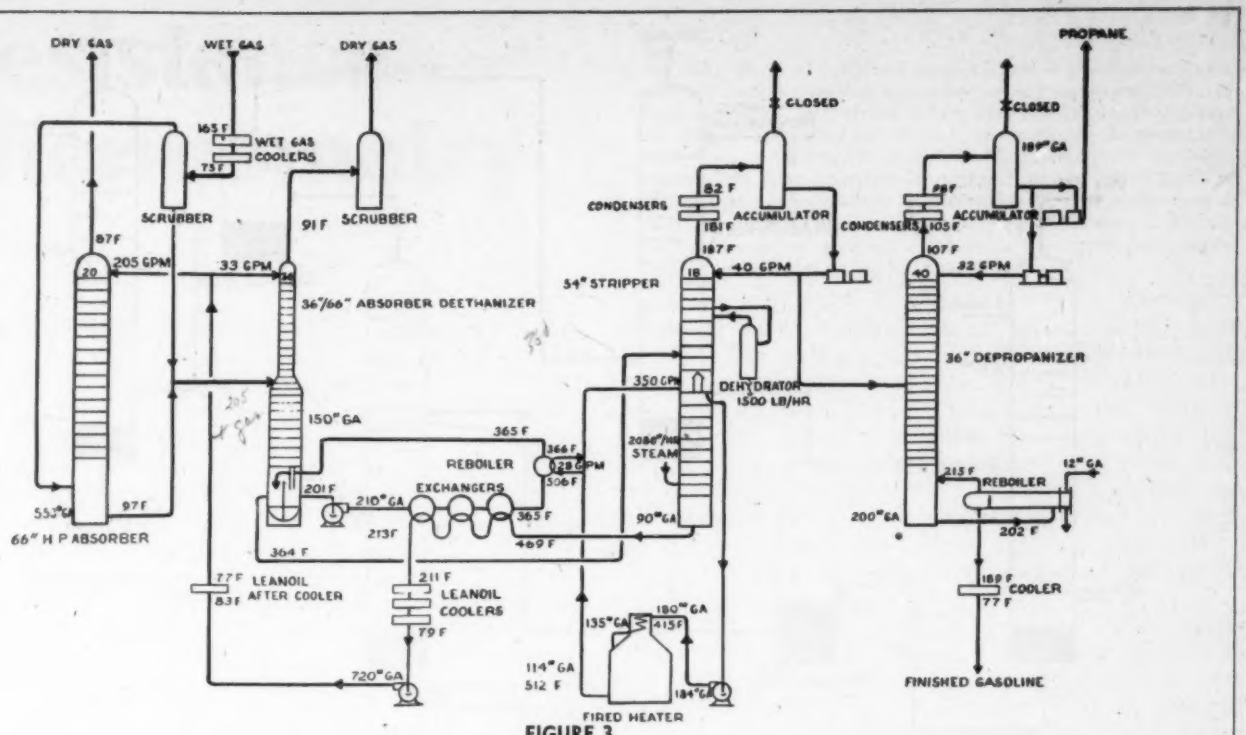


FIGURE 3
Plant A acceptance test.

has reboil. The unusual feature is that the reflux is lean oil, not condensed overhead.

Figure 2 shows the reboiler hookup. The liquid section in the bottom is divided into two compartments. Fat oil drops from the bottom tray into the left-hand side. It is then pumped through exchangers and into the right-hand side.

Temperature Differences

An important feature is the difference in temperature between the two compartments—the first section is some 200° F. as against 365° F. in the final section. These temperatures allow the use of countercurrent heat-exchange with the hot lean oil. The only direct heat used for reboiling the deethanizer is a small amount for hour-to-hour control of the final temperature.

Now for actual results. Figure 3 gives averages of temperatures, pressures, and flows for one acceptance test. Table 1 details the plant balance for the same test. Gas streams entering and leaving the plant are given at the top of Table 1. From these, balances on methane and ethane can be made, since none of these two go on with the liquid products. Accuracy of this balance is shown under material balance.

Butanes and pentanes are balanced in two ways, under recoveries. One way is by comparing gas-in and gas-out. The other is by comparing product in tanks with gas-in. The two methods check fairly well. Unfortunately, the liquid meter on propane failed. The volume could not be measured. Depropanizer overhead is obtained by subtracting bottoms and dry gases from wet gas. This is for C_3 plus only.

Initial operating conditions were set to closely follow those computed. It was almost three weeks later that the first test results were obtained. The results were a little surprising. Especially in the propane purity of some 99.5 percent.

A second test practically duplicated the first except that ethane in the propane was practically nil. Also propane production was some 2000 gallons per day greater. The third test was a quickie. Ethane in propane increased to a little over 1 liquid vol percent while recovery of propane went up to 78 percent of that absorbed. Later tests, we understand, gave about the same results. There was, at that time, no point in trying for increased propane of lower purity. First, the propane tanks were not ready. And second, time was not available for experimentation.

Limits

One natural question is, What are the limits of the fat-oil deethanizer? This is too big an order to cover all possible conditions. But we can give some ideas as to limits. The important point to keep in mind is the final bottom temperature. This is determined by two conditions: (1) pressure, and (2) amounts of propane and butanes in the bottoms.

Thus, lean gases are not so good for fat-oil deethanizing. The wet gas given in Table 1 is not far from the limit. Pressure depends finally upon propanes and butanes, once the temperature is set. For conditions of Figure 3 and Table 1, 150 psig in the deethanizer is not far from the limit. To sum up, the natural field of the fat-oil deethanizer is for gases that are at least as rich as, or richer than, the wet gas of Table 1.

Another point is heat recovery. This depends chiefly upon the bottom-tray temperature. In our test conditions this is about 200° F., we note from Figure 3. The final temperature is 365, or a rise of 150° F. As the richness of the gas changes, the big change is in the final temperature. The bottom tray does not change anywhere near as much.

Improved Fractionation

Another natural question is, can fractionation be improved? With respect to separating ethane from propane, the answer is yes, but not much. More oil would be put over the top of the deethanizer. And the final bottom temperature would be raised. This is in effect, increasing the reflux.

To help us find the proper niche for a fat-oil de-

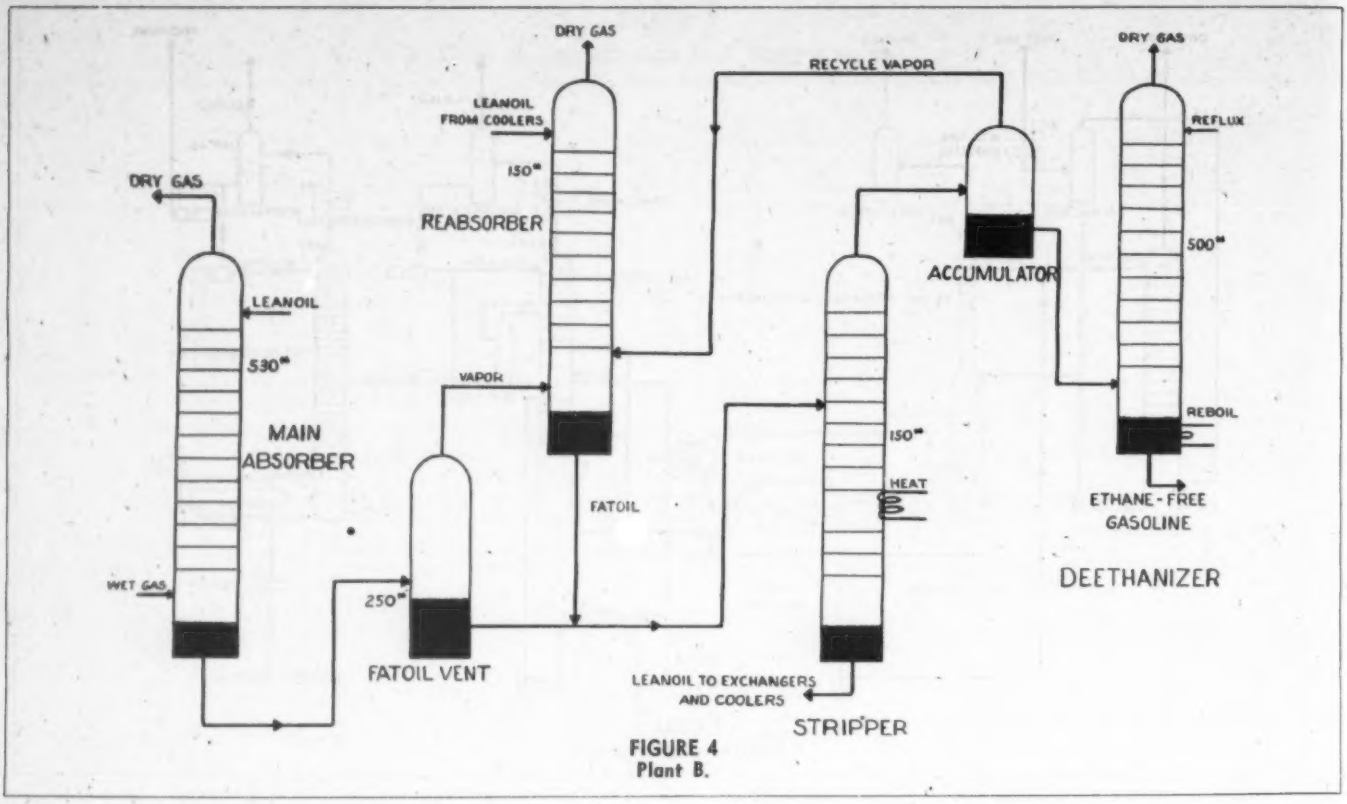


FIGURE 4
Plant B.

ethanizer, let us divide absorption plants into three main groups. First, where from 50 to 90 percent of propane, or more probably propylene, is recovered. The second, where propane can be readily marketed. But propane is still not worth expensive plants. Oil rates are set by butane recovery. Third, where propane cannot be sold as a product.

The fat-oil deethanizer does not fit the first case. Too much propane is still lost. And it does not fit the third case because of extra operating expense in fuel. It does appear to have a field in the second case, as the following analysis will show.

To make comparisons, we have chosen the unit shown in Figure 4. Call this Unit B. And the unit with the fat-oil deethanizer of Figure 1, Unit A. Unit B is a very common hookup. The reabsorber, or equal, must be included for vents from both flash drum and stripper accumulator to prevent loss of butanes. A single still is used at 150 psig. A gasoline deethanizer is included, partly to hold propane, and partly to prevent undue ethane contamination.

Production of propane for the two plants is shown in Table 2. Plant B has practically reached its limit in propane recovery. More butane and heavier is needed to hold the propane as liquid in the stripper accumulator. Increased oil over the reabsorber sends more propane to the stripper. But the additional propane simply returns as vapor to the reabsorber.

TABLE 2

	Unit A	Unit B
Gallons per day, about	12,000	7,100
Net gain, about	5,000	

Plant A returns about $52,000 yearly more than Unit B. This is gross return of course. To find net return, we must find first costs and operating costs. In the operating costs, let us set 10 cents per million Btu for fuel. And to be fair, we should deduct from the propane returns, its value as gas fuel at the plant boundary. Estimates of costs for the two units were made. Unit prices used in the estimates are those prevailing during construction of Plant A. Our estimate shows that the Plant A would cost about $40,000 less than the Plant B.

TABLE 3
Extra returns yearly, of Fat-Oil Deethanizer

Propane	$52,000
Less extra fuel	5,500
Less fuel value of extra propane	15,000
Other cost differences	
Net gain, say	$31,000

This gain still does not allow for the extra first cost of Plant B. Here is how we might make such an allowance. Say we wish to pay off original costs in four years. The man with the Plant A would have $165,000 more in his bank account than the man with Plant B. This sum consists of $120,000 made on extra propane, and $40,000 that he did not spend on the original plant. The average is some $40,000 per year for the four years.

All the foregoing assumes that propane can be sold as a product. What happens if propane liquid has absolutely no sale? Plant A costs $5,500 more per year to operate than Plant B. And the cost of Plant B goes down because the gasoline-deethanizer comes out. But the reabsorber stays in to hold butanes. Other items remain the same. The cost reduces by about $50,000. This credit seems low. A gasoline-deethanizer installed by itself costs much more.

But in making our estimate, the gasoline-deethanizer was given all the breaks possible in first cost. Miscellaneous expenses were not increased. And more than full allowance was made for simultaneous construction. Only $50,000 was put in for this column, so that is all we can take out.

This "no propane" picture makes the fat-oil deethanizer uneconomical, by the $5,500 per year for extra fuel. And the plant for no-propane costs a little less.

Resistance Thermometry

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EVERY phase of petroleum processing, from the drafting room, through construction and operation, is in a large way, affected by temperature. One of the oldest, and probably most accurate methods of measuring temperature, is Resistance Thermometery. This paper is intended to deal with the principles of operation, construction, and maintenance, rather than the glorification of the resistance thermometer or thermohm. It was prepared as a contribution to the Instrumentation Course of Southern California Meter Association, and was released to the association's membership as Publication No. 25, Paper No. 1.

OPERATION of a resistance thermometer depends upon the variation with temperature of the resistance of an electrical conductor.

Pure metals, when subjected to change in temperature, will have a like change in resistance. There are many characteristics necessary for an industrial resistance thermometer, the most important ones being reproducibility and constancy of resistance, and a convenient and simple relation between temperature and resistance.

Platinum in its purest form has the most desirable properties for use in thermohms up to a temperature of about 1000° C., and when properly calibrated it is possible to measure to 0.05° C.

For industrial work, the platinum thermohm is used between —40° F. and 800° F.

Nickel, having a very desirable relation between temperature and resistance in the lower temperature ranges and being more economical, is used for thermohms in the approximate ranges between —240° F. and +250° F. Copper is also used in the ranges between 0 and 350° F.

Resistance thermometers can be used where the temperature limits are within the suitable ranges, where it is possible to protect the element from contaminating gases and excessive vibration. Most of the above precautions hold true when using other means of measuring temperatures. Since its introduction by Siemens about 1871, and its improvement by Callendar in 1886, the resistance thermometer has been adapted for many uses, including primary standard between —40° C. and +450° C., measurement and control of temperature on aircraft, petroleum processing, air conditioning, refrigeration, and for any service where it is desirable to measure or control temperature to a very close degree of accuracy. Speaking of control, it is possible to indicate a differential temperature with an accuracy in the order of .0004° F. with resistance thermometers.

Resistance thermohms may be constructed in various ways to produce the desired shape, size and properties necessary for the job at hand. Probably the most common type used in petroleum refining is the 7½-inch platinum thermohm, which usually is made with about 24 inches of No. 39 especially selected platinum bare wire wound on a mica unit about 3 inches long by 5/16-inch diameter. The unit is built up on two pieces of mica, so arranged as to form a cross. The wire touches only the edges of the mica.

The winding is installed in a manner that will permit the start and finish of the unit to appear in the same general area with respect to temperature gradients to prevent any thermocouple effect, and for like reasons the extension wires from the platinum unit to the terminal head are made of gold or platinum in the caes of a precision standard unit, or of chromel in the industrial unit.

The wire is wound on the cross and spot welded to the terminals placed in its protector tube which is about ⅜-inch, outside diameter, thin-wall nickel tubing. The unit then is placed in a standard steam bath at atmospheric pressure. A reading is observed at approximately 212° F. and compared with the reading of a secondary standard in the same bath. The difference between these readings is recorded and considered as one of the tie points of this unit, with respect to the standard curve. Then the above procedure is carried out in an oil bath near 600° F. and the differential observed and recorded as the second tie point.

The differential at 212° F. is, say, 35° F. minus and at 600° is 50° F. minus. This indicates that the unit being calibrated must be made shorter by cutting out a small piece of platinum wire in the unit, about ⅛-inch. Then the above tests are repeated and additional cuts are made until the differentials are equal at each tie point. This means that we now have the curve for the unit being calibrated parallel with that of the standard unit, but approximately 41° F. minus. This differential will vary between 30° F. and 60° F. depending on the characteristics and properties of the platinum being used.

In order to shift the curve on the unit being calibrated so that it will match the standard curve, it is necessary to place a short length of manganin (zero coefficient) wire in series with the thermohm. This resistance is adjusted to make the unit read the same as the standard and is usually silver soldered to the terminals on the inside of the terminal head, there being four terminals, one for each of the A, B, and C legs of the thermohm and one for the pad coil, so that the differential may be determined at any time of future calibration. This two-point check serves very well for thermohms used in the middle temperature ranges. Where accuracy is needed throughout the full range, the practice is to calibrate at ice point, steam point, and the boiling point of sulphur.

These calibrations are made with a resistance bridge, using two slide wires so arranged as to give a constant one to one ratio. See Figure 1.

The slide wires "S" and "S_1" rotate together on

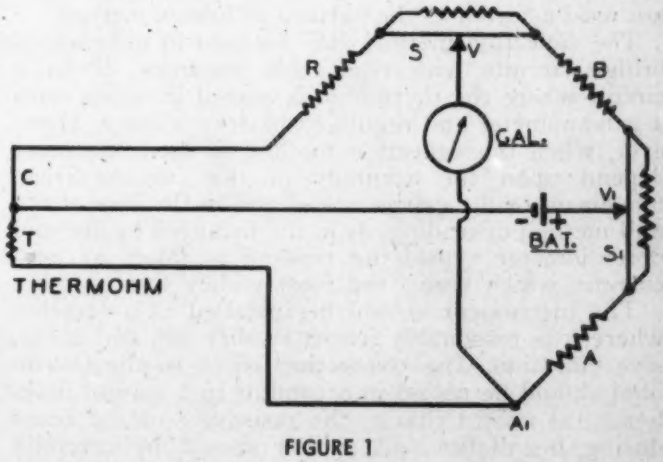


FIGURE 1

the same shaft, their resistance so proportioned by the contacts "V" and "V_1" on the slide wires that a constant one-to-one ratio is obtained on the two arms of the bridge. The resistance of the arm "VV_1" is always equal to the resistance of the arm "V_1A_1." The bridge is brought to balance by rotating the slides until the resistance arm "VRC" is equal to the resistance of "T" (the thermohm). With this circuit, the resistance of the leads from "R" to "T" and from "A_1" to "T" have no effect on the reading as long as these leads are of equal resistance.

As the contacts "V" and "V_1" are not in the measuring circuit, contact resistance at these points will have no effect on the accuracy of the reading. Likewise any normal variation in battery voltage will not affect the reading.

This method of measuring temperatures is desirable in many cases, as it is possible to design the bridge so that the full scale range is in the order of 20° C. and operating over such a narrow range it is possible to measure and control to a very close degree of accuracy.

The general principal of measurement is the same with all resistance thermometers; however, there are various types of instruments used for measuring the change in resistance of the unit.

The potentiometer method is one where the resistance is expressed in terms of a standard resistance, the ratio of which will depend on the ratio of the potential drops across two resistances when carrying the same current. See Figure 2.

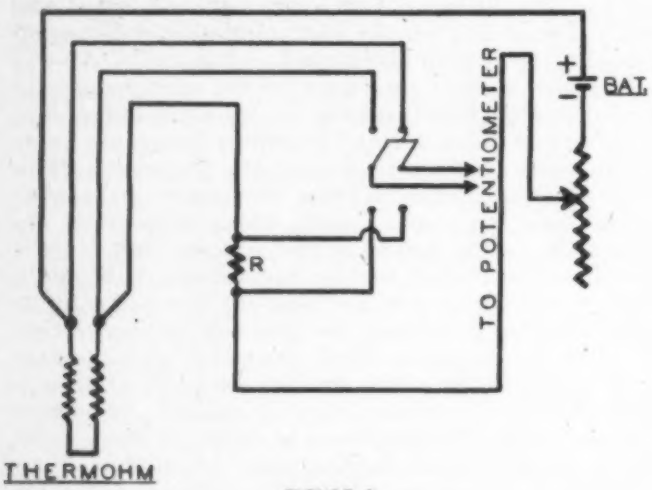


FIGURE 2

In this circuit the variation of resistance of the connecting wires have no effect on the accuracy. Due to a constant current being necessary, this method is not used as often as the balance or bridge method.

The deflection method may be used in unbalanced bridge circuits with reasonable accuracy, or in a circuit where the thermohm is placed in series with a galvanometer and regulated battery voltage. However, when the deflection method is used one must depend upon the accuracy of the current-driven movement of the galvanometer and in the case of the null method of reading, as in the balanced bridge and potentiometer types, the reading is taken at zero current, which seems the most widely used system.

The instrument should be installed in a location where it is reasonably free from dirt, oil, and excessive vibration. The connecting wires to the thermohm should be pulled in a conduit in a careful manner so as not to change the resistance of the wires during installation, all splices should be carefully soldered, as a change of resistance in the order of 0.018 ohms will mean 1 degree error in the case of the 10-ohm platinum thermohm described above. The Siemens three-wire method of compensation allows lead wires of considerable length. This system employs a bridge of constant one-to-one ratio, the "A" and "B" leads to the thermohm, being, in actuality, extensions of the bridge arms. If both these leads are of the same resistance and are pulled in the same conduit so that they have common changes in resistance, due to temperature changes along the conduit run, the circuit conditions have been complied with. Such leads can be extended without changing accuracy but with a loss in sensitivity which can be compensated for by raising battery voltage. Battery voltage should, however, be low enough that the current through the masuring coil will not generate enough heat to affect t' . alibration.

The lead wires may be checked at the time with a standard check coil designed to work with the instrument to be used. It is connected to the thermohm end of the circuit and a reading taken with the instrument. It should read the temperature indicated on the check coil if the "Z" and "B" legs of the circuit are of equal resistance. If it reads high, it means that the "A" leg is higher in resistance than the "B" leg. This, of course, is true if the instrument has been checked with the check coil connected directly and found to be correct.

In some cases, it will be found that two of the three wires will be of equal ohmage and the one that is off can be used for the "C" leg. If this is not the case, then after it has been proven that it is not padding an intermittent circuit, the "A" or "B" circuit may be padded with manganin wire to make them of equal resistance.

The instrument and circuits may be checked periodically with a check coil, which will detect worn slide wires, faulty circuits, and lack of sensitivity.

This check coil is a non-inductive coil wound with manganin wire to an ohmage that meets the specifications for a designated temperature within the range of the instrument being tested.

Multipoint instruments of resistance type have selector switches that are operated either manually or by motor-drive. These switches must be kept clean and well lubricated by a clean non-corrosive oil as this switch will normally switch the "A" and the "C" circuits, and any change in contact resistance here will introduce an error in the readings.

A spare point on the instrument connected to a check coil will serve as a continuous check on the overall accuracy of the instrument.

Advantages in use of Resistance Thermometers.

1. Can be designed to have a greater accuracy than other types of temperature measurement.
2. Greater distance allowable between instrument and thermohms than with the direct-expansion types.
3. Lower temperatures can be measured than with the pressure-type thermometer.
4. Can be used effectively in the range of normal ambient temperatures where the thermocouple is not dependable.
5. Not critical to normal changs in operating voltage.
6. Requires no cold-junction correction.
7. Cost of copper leads as against compensating lead wire.

Disadvantages in Use of Resistance Thermometers

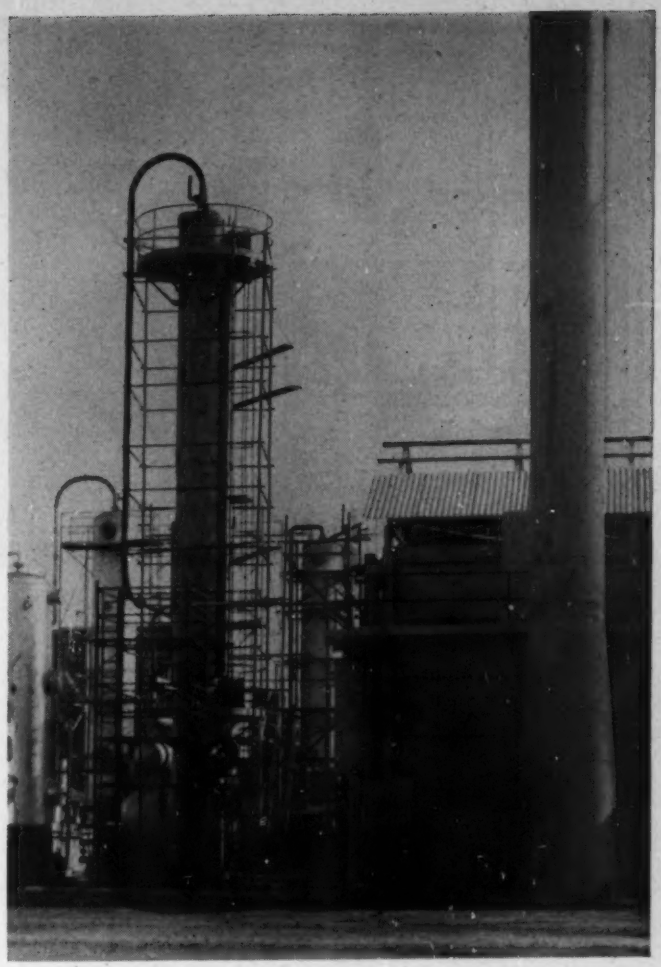
1. Initial cost of the thermohm.
2. It is affected by excessive vibration.
3. Platinum absorbs metallic vapors when operated at high enough temperature to show color—approximately 900° F. This alloys the platinum and changes the calibration. In this it is similar to any platinum thermocouple and if protected by proper ceramic tubing a thermohm may be used at elevated temperatures.
4. The necessary precautions in the extension lead wires.

Thermal Reforming Unit Improves Naphtha Octane Rating

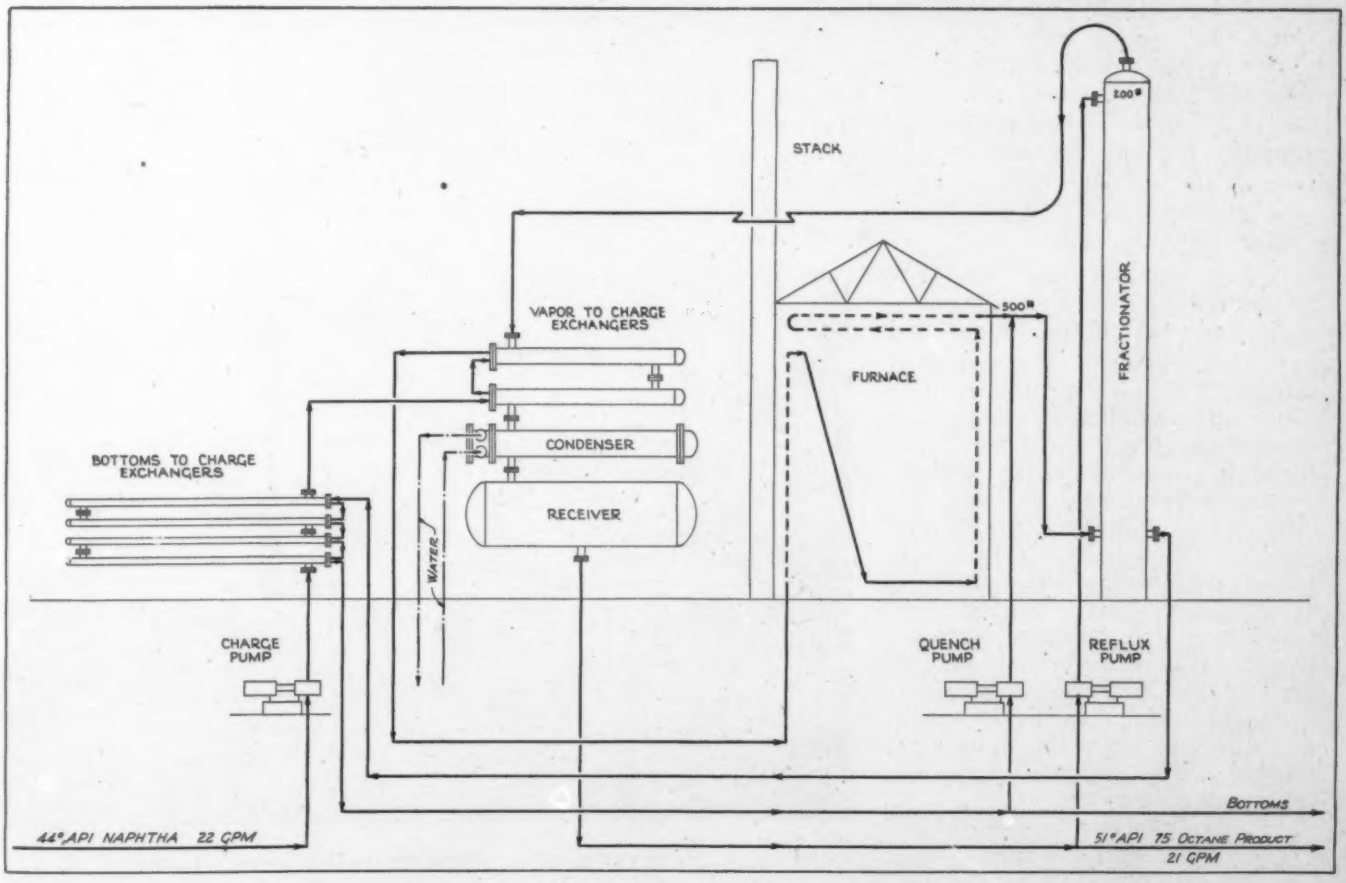
REFORMING a low-octane naphtha into a high-octane product for blending stock is one of the operations accomplished by The Caminol Company in its refinery at Hansford, California. The naphtha charged has a consistent gravity of 44° API and octane rating of 45-47, while the reformed product has a gravity of 51° API and octane rating of 75, with distillation range from 90° F. initial to 390° F. end point. The operation is performed with a loss of only 9.5 percent, principally gas which is further processed through a subsequent absorber from which uncondensible fractions are piped to the refinery-fuel system.

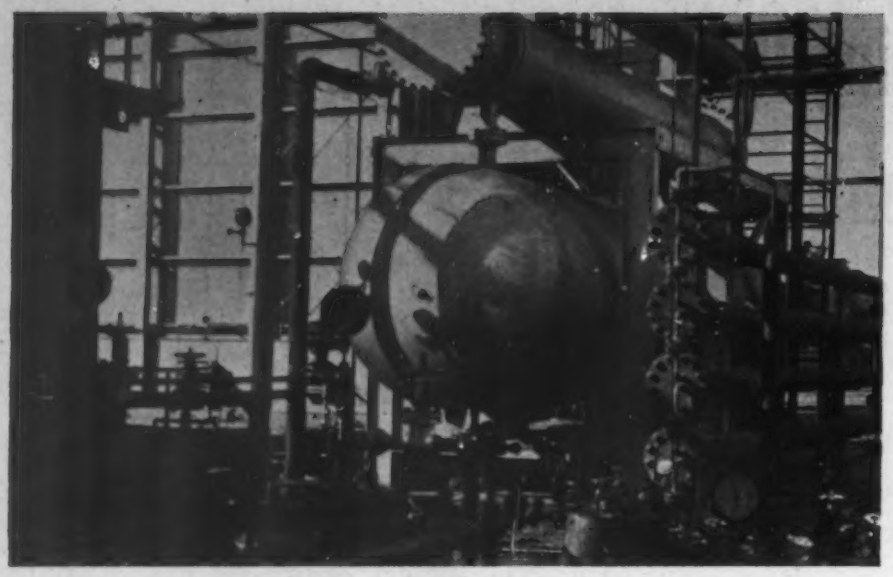
The reforming unit was designed by The Caminol Company's engineers as a wartime expedient to produce commodities entering into high-octane motor fuel, and was completed in the early summer of 1945. The unit in postwar operation is producing a stock ideally suitable for motor fuel when blended with other products of the refinery, as the reformed product has good lead susceptibility.

The reforming unit is compact and is located within the area of the principal units of the refinery. It,



Reformer used by The Camanol Company to reform 44 API naphtha into 51 API gasoline having an octane rating of 75. Below is a flow diagram of the installation.





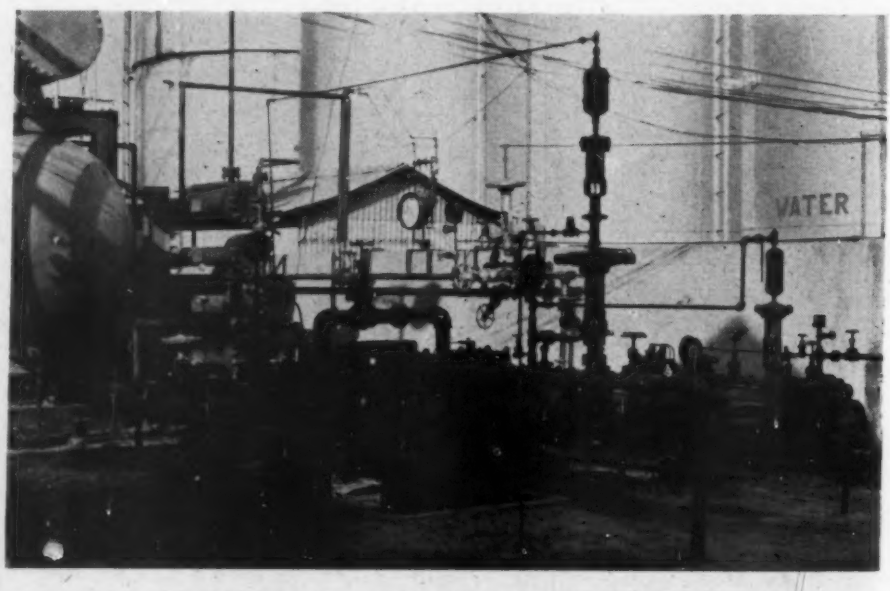
Bottoms-to-charge exchangers installed beside liquid receiver

however, is complete within itself, containing its own furnace, pumps, fractionator and water system. It is dependent upon the remainder of the plant for the stock with which it is charged, and is connected in such a manner with the thermal-cracking unit that the condensate from the fractionating column may be passed into a transfer system with the product from the cracking plant. The reformer production is handled separately from all other material in the plant, and remains separate until it is used as blending stock for motor fuel. The raw product is stabilized to the Reid vapor pressure most suitable for current use, and the undesirable and uncondensed fractions are passed through an absorber for recovery of what might have been carried over in the vapor state.

The furnace of the reforming unit is designed for 8,500,000 Btu per hour, and has 1,750 square feet of effective surface. The fuel may be either oil or gas supplied to three combination burners. The temperature of the furnace and of the commodity passing through the tubes is controlled by a recorder-controller through a pressure balanced valve on the fuel-gas line. The naphtha charge stock is pumped to the furnace by a horizontal 10 x 3 x 12 duplex steam pump at a normal rate of 22 gallons per minute. The commodity handled by this pump flows through a 1½-inch line, first, through a vertical bank of 4 shell-and-tube bottoms-to-charge exchangers, each unit having a 6-inch shell and each is 240 inches long, containing a total of 164 square feet of exchangers surface. From these exchangers the naphtha is transferred to a vertical bank of two fractionator overhead-to-charge exchangers which are 14 inches in diameter and 176 inches long, containing a total of 244 square feet of exchanger surface.

The naphtha is processed in the furnace through a bank of wall tubes in the stack end of the heater, thence by cross-over to a similar bank in the burner end, and finally through a double row of tubes installed in the roof. The pressure maintained on the commodity at the outlet of the furnace tubes is 500 psig, and the final temperature is held at 1,050° F. To remove the "sting" of the high temperature from the material leaving the furnace, bottoms from the fractionating column are pumped by a motor-driven, constant-speed pump which is set to deliver 6 gallons per minute. This quench is introduced into the circuit between the outlet of the furnace and the control slide valve so that the temperature of the commodity entering the fractionator is maintained at 975° F.

This fractionating column is 42 inches outside diameter and 44 feet high, contains 16 bubble pans and 4 side-to-side trays. It is operated at a pressure of 200 psig, and reflux is pumped to the top section at the rate of 22 gallons per minute, or with a ratio of 1:1, feed to furnace and reflux to the column. The pump employed to deliver reflux from the overhead vapor condensate receiver is a simplex 5 x 5 x12. The overhead vapors pass through an extra heavy 6-inch vapor loop to the vapor-to-charge exchangers and pass downward to a single condenser unit, 24-inch shell by 192 inches long, containing 1,220 square feet of surface. Water for cooling the vapors is pumped from the basin of a tower built especially for the reformer unit, by a single-stage centrifugal pump. Condensate and gas flow downward to the receiver below the condenser, and the reformed product flows to storage through a stabilizer to obtain the desired Reid vapor pressure before blending. Gas from the receiver passes to an absorber operated at 40 psi to recover any valuable fractions before the residue enters the refinery fuel lines.



Pump setting in the reformer unit of The Caminol Company

Fractionation of Petroleum

DR. N. MAYER

Translated by E. J. Barth, Petroleum Technologist—"Oel u Kohle," No. 2, Jan., 1943

IN ORDER to design a properly functioning fractionating column, as well as to superintend the operation of a complete system of distillation equipment, it is of prime necessity that certain physical properties of petroleum be reviewed and understood.

The many constants on petroleum functions necessary to characterize all their properties which can be determined in the laboratory are not always readily found in the literature; moveover, many of these physical tests are fairly complicated and are tedious procedures belonging in the physics laboratory.

The constants most important to determine or evaluate in any study of petroleum fractionation are the boiling-point determinations, specific gravity, specific heat, heat of vaporization, thermal capacity, critical data, molecular weights, etc. Accurate data is fairly well scattered in the literature and rather meager. We will, therefore, discuss these constants and show where they enter the calculations in fractionation problems.

Latent Heat of Vaporization

Latent heat of vaporization, according to definition, is the quantity or amount of heat which must be employed to convert unit or total weight of product at its boiling point into vapor at the same temperature. According to definition, the underlying notion of heat vaporization is further distinguishable into inner and outer heat of vaporization. The outer heat of vaporization is the external work, expressed as heat units, which must be furnished to secure vaporization. This amount of work is employed or used in offsetting or overcoming the external pressure. Its value in absolute vacuum is therefore zero. The internal heat of vaporization is the energy difference, expressed in heat units, between the saturated vapor and equilibrium or saturated liquid. Its value is dependent on the nature of the fluid and is a constant at given temperature and pressure.

These relationships can be viewed as follows, keeping in mind the main important items in the kinetic theory of liquids.[1]

The molecules of an ideal fluid can be postulated as consisting of complete, separate, equally elastic, round balls which cannot be compressed together—incompressible. The attractive or adhesive power of the molecules is equal in all directions so that these forces are mutually neutralized or annulled.

In the interior of the fluid the molecules therefore behave toward one another as if they experienced no force or forces from any neighboring molecule. Conditions are quite different at the surface of the liquid, or say oil-air interface, since in this case no such compensation can take place. The forces on the one hand will exert their power out beyond the surface, while on the other hand the molecules right in the surface will experience a pull in the direction of the inside or interior of the liquid. This pull toward the interior has practically the same effect as a corresponding use in external pressure. This apparent rise of an external pressure is designated as internal pressure.

Since during any vaporization the molecules must be brought up to the surface from the interior of the liquid, a definite amount of work must be exerted which is employed and used to overcome the attractive cohesive between the molecules. But since the molecular forces also exert attractions beyond the surface of a liquid, and whose effects become vanishingly small in the vapor phase, an additional amount of energy must be fed into the system in order to transfer the molecules from the surface or interface into the vapor proper.

Let a designate the total work or energy required to transport the molecules from the surface of a liquid into the vapor state, n the number of molecules in a Kgm. of liquid, and E the mechanical equivalent of a calorie, then $\frac{an}{E}$ small calories are required to vaporize a Kg. of the liquid.

From what has been said previously, the magnitude of the heat of vaporization is dependent on the value of the internal pressure.

The Clapeyron-Clausius equation is used in connection with calculations for heat of vaporization:

$$r = T \frac{\alpha p}{\alpha T} (V_1 - V_2) \quad \ldots\ldots (1)$$

where, p = vapor pressure
T = temperature, °K
r = heat of vaporization.
V_1 V_2, the respective volumes of vapor and liquid.

Since the volume of liquid compared to the vapor volume is very small one can neglect the liquid volume so that the expression assumes the form:

$$r = T \frac{\alpha p}{\alpha T} V. \quad \ldots\ldots (2)$$

Boyle-Charles law expresses the vapor-volume relative to the weight-mass of vapor:

$$V = \frac{RT}{Mp}$$

The expression for v can be substituted in the above equation, obtaining:

$$r = \frac{RT^2}{Mp}\left(\frac{\alpha p}{\alpha T}\right) \text{ or}$$

$$\frac{\alpha p}{p} = \frac{rM}{R}\left(\frac{\alpha T}{T^2}\right) \quad \ldots\ldots (3)$$

Integration of this expression gives:

$$\ln p = -\frac{rM}{R}\left(\frac{1}{T}\right) + \ln C \quad \ldots\ldots (4)$$

This equation can also be written:

$$2.3 \log p = -\frac{rM}{R}\left(\frac{1}{T}\right) + 2.3 \log C \quad \ldots\ldots (5)$$

r can now be calculated without difficulty since p,

the boiling point at normal pressure 1 Kgm. per sq. cm., and all other units, except c, are known.

G. Jaeger has shown in a mathematical contribution[2] that constant c is merely the internal pressure P, and he arrives at the final formula:

$$p = Pe\left(\frac{rM}{RT}\right) \quad \ldots\ldots(6)$$

The internal pressure can be calculated for liquids whose physical properties are known. Jaeger further shows that it is possible in the case of ideal liquids to calculate the internal pressure from the compressibility coefficient (K), and the expansion coefficient (a). He derives the following expression:

$$P = \frac{a}{K}T \quad \ldots\ldots(7)$$

Jaeger finds a value of 20,000 Kg. per sq. cm. for mercury, which very closely resembles an ideal fluid. Both methods of calculation were used and found to check.

Since the internal pressure can now be derived from the expansion and compressibility values, and knowing the magnitudes of these values, which can be measured, one can now calculate the heat of vaporization purely thermodynamically; it must be pointed out that in calculations dealing with mercury the molecular weight of mercury is equal to the atomic weight.

$R = 0.848$ Kg/m, $T = 623$ deg.K, $p = 1$ Kg/sq. cm.

$$2.3 \log 1 = -\frac{r(200)}{0.848 \cdot 623} + 2.3 \log 20000.$$

$$r = \frac{2.3 \log 20000 \times 0.848 \times 623}{200} = 26.12 \text{ Kg/m.}$$

$$= 61.2 \text{ g cal./g}$$

This value is in very good agreement with experimentally determined values for heat of vaporization of 62 g cal. For liquids which deviate more strongly from the ideal fluid due to their greater compressibility, the method does not appear applicable.

Now, if the values for the vapor pressure of a liquid are known for two closely placed or adjacent temperatures, T and dt, the heat of vaporization can be calculated from the Clapeyron equation provided the corresponding value for the volume and molecular weight are known.

These values or constants are not well known or easily accessible for petroleum and its fractions. One must therefore be content in practice to use empirically derived simple formulae and rules for such calculations. Some of the more important formulae will now be discussed. One such formula is the well known Trouton law:

$$rM = KT \quad \ldots\ldots(8)$$

where, v = heat of vaporization small cal./Kgm.
M = molecular weight
K = Trouton's constant
T = B.P. in °K. at atmospheric pressure

Constant K lies between 19 and 23 for petroleum hydrocarbons. A useful average would be 21.5.

Nernst[3] varied the equation to read:

$$rM = T(9.5T - 0.0007T) \quad \ldots\ldots(9)$$

It should be mentioned that the author has derived a relation between molal heat of vaporization and temperature in °C., which between the range of —50 and + 400° C., gives values in good agreement with the observed values presented in Table 1.

TABLE 1
Relationship Between Molal Heat of Vaporization and Boiling Point

MATERIAL	B. P. °C.	Mr (cal'd) for 1 gm mol in Small Cal.	Mr (Found) Small cal./g Mol.	Observer
n-Heptane	98	7.66	7.4	Maberry
n-Pentane	36	6.3	6.12	Young
Benzole	80.2	7.28	7.45	Young
Benzole	80.1	7.28	7.25	Wirtz
Toluol	110.8	7.92	7.69	Shiff
Ethyl-Benzole	134.7	8.42	8.1	Shiff
m-Xylol	139.9	8.5	8.3	Shiff
n-Octane	125	8.2	8.1	Louquinine
Acetophenone	203.7	9.87	9.3	Louquinine
Mercury	350	12.95	12.4	Person
Ethyliodide	72	7.11	7.17	Kahlenberg
Ethyliodide	72	7.11	7.3	Andrews
Acetone	56	6.77	7.27	Wirtz
Amyl Propionate	161	8.98	9.09	Shiff
HBr	—68.7	4.16	3.94	Estreicher & Schnerr
H_2S	—60	4.34	4.5	Estreicher & Schnerr
N_2	—196	1.48	1.34	Alt
HCl	—85	3.82	3.60	Estreicher
Aniline	184	9.46	9.77	Shiff
Iodobenzole	188	9.55	9.45	Young
Cadmium	767	21.7	23.7	Braune
Decane	159.45	8.95	8.6	Louquinine
H_2SO_4	326	12.4	11.97	Person

The above-mentioned empirical relationship is expressed as follows:

$$Mr = 5.6 + 0.021t \quad \ldots\ldots(10)$$

where Mr is the molal heat of vaporization in cal. per gm. mole. and t, boiling point in °C at atmospheric pressure.

The most interesting relationship between boiling point and molal heat of vaporization at atmospheric pressure was developed by W. Kistiakowski.[4] This relation contains only rational units, and values calculated by this equation agree well with observed data in all ranges of temperature. One desires to see the Kistiakowski equation placed in our modern text books on this subject since this equation furnishes more accurate values than Trouton's rule. This Kistiakowski equation takes the following form:

$$Q = V \ln V \quad \ldots\ldots(11)$$

or $$Q = RT \ln RT \quad \ldots\ldots(11a)$$

At atmospheric pressure:

$$1 \times V = RT$$

where Q = molal heat of vaporization
V = molal volume in cu. cm.
T = the Boiling Point in °K. at atm. pressure
R = the gas constant

The value of Q in small calories per Kgm-mol is then evaluated by substituting numerical values, using logarithms:

$$Q = 1.985\,T\,(2.3 \log 82.06\,T) \quad \ldots\ldots(12)$$

or $$Q = 4{:}571\,T\,(\log 82.06\,T) \quad \ldots\ldots(13)$$

From a study of Kistiakowski's work it is not quite clear whether his newly developed equation is thermodynamically founded, that is, by what thermodynamic reasoning can one arrive at such a relationship.

The expression RT·ln RT is by no means unknown in thermodynamics. Van der Waals[5] says as follows:

"RT times the natural log of this expression is equal to the thermodynamic potential up to a point dependent on T, a point which is, at various times, without significance to the relation of thermodynamic potential."

Comparing Trouton's rule with the Kistiakowski formula it is seen that the Trouton constant comprises or results in the value R(ln RT); one may write:

$$K = R \ln RT \quad \ldots\ldots(14)$$

From this, it is seen that K cannot actually be a constant since it can be made to vary with temperature. The expression set up for K explains also why Trouton's rule is only valid or can be used in cases

where K fits some suitable boiling point, i.e., not limited to some definite constant value.

By substituting equation (11a) in equation (6) we obtain:

$$P = \frac{P}{e^{\ln RT}} \quad \ldots\ldots (15)$$

From this equation the internal pressure can now be easily calcuated from the single known boiling point at atmospheric pressure; the value of R is 82.06/1 atmosphere.

The integration constant C in equation (4) is equal to the magnitude P, as mentioned above; it is evident since equation (4) can be written in the following form, using instead of the logarithm, the value of the log itself:

$$P = \frac{C}{e^{\frac{Mr}{RT}}} \quad \ldots\ldots (16)$$

Similarly, one can substitute the expression RT (ln RT) for Mr, obtaining the following form of the equation:

$$P = \frac{C}{e^{\ln RT}} = Ce^{-\ln RT} \quad \ldots\ldots (17)$$

Since pressure p = 1 atm. at the boiling point at 1 atmosphere, we have further:

$$P = C = e^{\ln RT} \quad \ldots\ldots (18)$$

For instance, calculating P for hexane (B.P.=68°C.) one will obtain for P a value of 27730 Kgm. per sq. cm. If one now substitutes this value in equation (5) and solving for r, we obtain:

$$r = \frac{2.3 \times 4.44278\ (0.848)\ 341}{86.1} = 34.1 \text{ Kg/m/g.}$$

or 79.7 gm. cal./g. The experimentally determined value is 79.9 gm. cal./g. The agreement is very close, especially if one keeps in mind that the above solution was calculated by slide rule.

All these equations are valid only for non-associated liquids, in other words, therefore, not for water. In the case of associated liquids, heat of vaporization is affected by heat of association; since the latter may be positive as well as negative, the calculated heats of vaporization can easily be greater or less than the observed values, or in some cases, also equal to the observed values. Furthermore, these equations are also only valid for the boiling point of materials at atmospheric pressure. For pressures other than atmospheric one can calculate the heat of vaporization provided the change in external work energy is taken into consideration. The results, however, become less accurate as one approaches the critical point, since the internal heat of vaporization decreases when approaching the critical point.

To calculate heats of vaporization at other temperatures, from the value of r at the boiling point at atmospheric pressure, the formula of Thiessen[6] is of value:

$$r_2 = r_1 (1-\alpha)^{1/3} \quad \ldots\ldots (19)$$

where v_2 = heat of vaporization (in Kgm. cal./Kgm. at temp. T.
v_1 = heat of vaporization at the Boiling Point at atmospheric pressure.
d = Temperature T : T_k.

In the case of mineral oils where molecular weights are not definitely known, the calculation for molar heat of vaporization becomes in such cases meaningless.

It is very difficult to find trustworthy formulas in the petroleum literature or data for calculating the molecular weight or heats of vaporization based on the mass behavior of petroleum fractions undergoing distillation and fractionation. American investigators have therefore paid more attention to deriving more reliable data (perhaps as much empirical as before) but mainly to carry out accurate calculations for design and correct operation of plant equipment for highest efficiency. So far, however, some newly derived formulas still leave much to be desired.

We will now elucidate on the more common, well known formulae in greater detail:

(A) Formulae to calculate heat of vaporization for average mixtures of petroleum hydrocarbons, and where the molecular weight is not necessary in the calculation:

(1) Cragoe's formula[7]

$$L = \frac{1}{d}(110.9 - 0.09t) \quad \ldots\ldots (20)$$

where L = heat of vaporization in Btu per lb.
d = specific gravity at 60° F.
t = temperature °F.

(2) Weir and Eaton's formula[8]

$$L = 241 - 102d - t\,(0.396 - 0.361d) - t^2\,(0.000078d - 0.0002) \quad \ldots\ldots (21)$$

L = again ht. of vaporization Btu. per lb.
d = density at 60° F.
t = temperature in F.

(B) Further calculations for latent heats of vaporization:

The author has occupied himself with the problem to find a method with which it is possible to calculate latent heats with some degree of accuracy of petroleum hydrocarbon mixtures whose molecular weight is unknown. The procedure was as follows:

It has been seen that molal heat of vaporization of a compound can be reasonably calculated with a good degree of accuracy from the absolute temperature. On the other hand, it is known that the heat of vaporization for the unit mass of a hydrocarbon lies in general between 25 and 100 small calories. One could theorize that it ought to be possible also to develop a formula (by selecting a chosen average value for the heat of vaporization) which would make possible to calculate mole weights from boiling points. Employing for this purpose, for instance, Trouton's law:

$$Mr = KT$$

then the molecular weight is related as follows:

$$M = \frac{KT}{r} \quad \ldots\ldots (22)$$

One can now substitute an average value for r, namely 70, thus obtaining:

$$M = \frac{KT}{70} = \frac{21.5T}{70} \quad \ldots\ldots (23)$$

This formula does not satisfy many conditions, due to its inflexibility. This formula can, however, be made more useful by substituting t + 273 in place of T; one obtains:

$$M = \frac{273K}{r} + \frac{K}{r}t = \frac{273(21.5)}{70} + \frac{21.5}{70}$$
$$t = 84 + 0.308t \quad \ldots\ldots (24)$$

One has now a basic formula which by suitable substitutions for r, and by greater application will yield a certain and closer approximation to the truth. By means of step-wise empirical mathematical treatment one can obtain a form such as $M = 84 + at + bt^2$, which enlarges the scope of better evaluation and closer agreement with actuality. In this manner the author has obtained the following relationships for the calculation of mole weights for several hydrocarbon groups; the calculations are based on the boiling point of the respective hydrocarbon or its

TABLE 2

Actual and Calculated Molecular Weight of the Paraffins

PARAFFIN	B. P. °C. at 1 atm.	Mol. Wt. (M)	Mol. Wt. (Mb) Cal'd*
C_6H_{14}	60.2	86.0	83.4
C_6H_{14}	68.0	86.0	86.1
C_8H_{18}	125.6	114.0	112.7
C_8H_{18}	119.0	114.0	109.4
$C_{10}H_{22}$	174.0	142.0	141.0
$C_{10}H_{22}$	166.0	142.0	136.0
$C_{10}H_{22}$	161.7	142.0	133.4
$C_{12}H_{26}$	216.0	170.0	169.5
$C_{12}H_{26}$	210.0	170.0	165.0
$C_{12}H_{26}$	234.0	184.0	182.8
$C_{12}H_{26}$	221.0	184.0	172.9
$C_{14}H_{30}$	552.5	198.0	197.2
$C_{15}H_{32}$	270.0	212.0	212.0
$C_{16}H_{34}$	287.0	226.0	226.5
$C_{16}H_{34}$	267.5	226.0	209.3
$C_{18}H_{38}$	317.0	254	253.8
$C_{19}H_{40}$	330.0	268	255.0
$C_{20}H_{42}$	344.0	283.0	280.0
$C_{28}H_{58}$	405.0	352.0	346.0
$C_{28}H_{58}$	446.0	394.0	394.5
$C_{30}H_{62}$	461.0	422	413

*By $M = 64 + 0.25t + 0.0011t^2$

TABLE 3

Actual and Calculated Molecular Weights of Olefins

OLEFINE	B. P. t °C.	Mol. Wt. M	Mol. Wt. Mb (Cal'd)*	Molal Ht. or Vaporization Mr/M	Mr/Mb
C_6H_{12}	68.0	84.	84.4	83.7	83.4
C_8H_{16}	124.	112.	110.2	73.3	80.3
$C_{10}H_{20}$	172.	140.	139.1	61.0	61.3
$C_{15}H_{30}$	270.	210.	218.4	53.6	52.0
$C_{15}H_{30}$	260.	210.	209.5	52.4	52.5
$C_{18}H_{36}$	312.	252.	260.5	51.6	49.3
$C_{31}H_{42}$	350.	296.	305.5	46.8	45.5

* By $M = 65 + 0.19t + 0.0014t^2$

TABLE 4

Actual and Calculated Molecular Weights for Cycloparaffins

CYCLOPARAFFIN	B. P.	Mol. Wt.	Mol. Wt. Mb (Cal'd)*
C_6H_{12}	81.0	84.0	84.2
C_7H_{14}	115.0	96.0	96.2
C_8H_{16}	147.0	112.0	112.3
C_9H_{18}	172.0	126.0	124.1
C_9H_{18}	199.0	126.0	138.9
C_9H_{18}	145.0	126.0	110.5
C_9H_{18} (Aver.)	172.0	126.0	124.1
$C_{10}H_{20}$	166.0	140.0	139.8
$C_{10}H_{20}$	157.0	140.0	133.4
$C_{10}H_{20}$	171.0	140.0	143.2
$C_{10}H_{20}$ (Aver.)	.....	140.0	139.0
$C_{11}H_{22}$	191.0	154.	158.7
$C_{12}H_{24}$	206.	168	171.0
$C_{13}H_{26}$	204.	168.	169.0
$C_{13}H_{26}$	230.	182.	183.0

* By both the above-given formulae for cycloparaffins. Tables II-IV show Mol. Wts. and B. P. as taken from "Science of Pet. Vol. II, New York, 1939."

series. The relationships are valid for hyrdocarbons containing over five carbon atoms.

1. For the paraffins:

$$M = 64 + 0.25t + 0.0011t^2 \quad \ldots\ldots (25)$$

2. For olefins (C_nH_{2n}):

$$M = 65 + 0.19t + 0.0014t^2 \quad \ldots\ldots (26)$$

3. For cycloparaffins (C_nH_{2n}):

$$M = 64 + 0.16t + 0.0011t^2 \text{ (to } C_9H_{18}) \quad \ldots\ldots (27)$$

4. For the higher members of this series:

$$M = 64 + 0.19t + 0.0016t^2 \quad \ldots\ldots (28)$$

Tables 2, 3, and 4 show the comparison between actual mole weight and the weights calculated by the abcve formulae. It must be remembered that in the case of individual isomers some corresponding deviations must needs result, since mol weight remains constant, the boiling point being slightly different. One can now calculate the molal heat of vaporization from the boiling point on the one hand, and the molecular weight on the other hand.

The unit heat of vaporization is obtained from both these values.

An example:

We have before us a hydrocarbon of boiling point 68° C. and a specific gravity of 0.655 at 15° C.; the U.O.P. characterization factor calculates to be 12.85; the hydrocarbon is, therefore, obviously paraffinic. Molar heat of vaporization:

$Mr = 5.6 + 0.021\ (68) = 7.0$ or 7000 small calories/Kg-mol. The mole weight calculates to be 86.1. The heat of vaporization, therefore, is 81.3 small calories/Kg. Normal hexame shows 86. as mole weight, a boiling point of 68° C., and heat of vaporization of 80 small calories/Kgm. The agreement is satisfactory, since the error is only 1.6 percent.

B. The Specific Heat For Fluid Hydrocarbon Mixtures

The most familiar empirical formulae are:

1. The Fortsch & Whitman formula[9]:

$$C = \frac{(t + 670)\ (2.1 - d)}{2030} \quad \ldots\ldots (29)$$

where:

C = spec. heat in Btu per lb. per ° F or ° C at t ° F.
d = spec. gravity at 60° F/60° F.
t = temp. ° F.

2. The formula of Cragoe[10]:

$$C = \frac{1}{\sqrt{d}}\ (0.388 + 0.00045t) \quad \ldots\ldots (30)$$

where:

C = spec. heat in Btu per lb. per ° C. or ° F. at t° F.
d = same as in (29)

3. The Watson and Nelson formula[11]:

$$C = [0.6811 - 0.308d + t(0.000815 - 0.000306d)]\ (0.055K + 0.35) \quad \ldots\ldots (31)$$

where C = spec. heat; d, and t same as in (29) and where K = U.o.P. characterization factor.

C. Specific Heat of Oil Vapors

Use the formula of Watson and Nelson[12]:

$$Cp = \frac{4.0 - d}{6450}\ (t + 670)\ (0.12K - 0.41) \quad \ldots\ldots (32)$$

The units are the same as in the above formulae.

D. Thermal Capacity

1. Gould's formula for liquid oils[13]:

$$H = \frac{1}{\sqrt{d}}\ (0.388t + 0.000255t^2 - 12.65) \quad \ldots\ldots (33)$$

where H = thermal capacity per lb. over 32° F.
d = spec. gravity at 60° F.
t = ° F.

2. Thermal capacity for oil vapors by Weir and Eaton[14]:

$$H = (215 + 87d + 0.415 - 0.104d)t + (0.00031 - 0.000078d)t^2 \quad \ldots\ldots (34)$$

where H = thermal capacity at 1 atm. in Btu./16 over 32F.
d and t same as above.

For those who prefer the metric system of units instead of the American method, the formulae in A to D can be transposed by substituting the suitable following values:

Right Hand	Left Side or Left Hand
L is substituted by 1.8L	Corresponds to 0.555L
C is substituted by 1.8C	Corresponds to 0.555C
t is substituted by (1.8t+32)	Corresponds to (0.555t—32)
H is substituted by 1.8H	Corresponds to 0.555H
T is substituted by (1.8t+492)	Corresponds to (0.555T—492) + 273

(60F. = 15.5° C; 32F = 0° C.)

For L, C and H one obtains them small calories,

substituting °C for t in temperature. One would then not have to change the constants and multipliers in the equations. For instance, formula (20) would then assume the following form:

$$0.555L = \frac{1}{\sqrt{d}}[110.9 - 0.09\,(1.8t + 32)]$$

The same applies to the following formulae where the energy units and conditional units are expressed in the American (engineering) system.

E. U.O.P. Characterization Factor, K

U.O.P.Characterization Factor, K[15] is based on the following considerations: when petroleum is separated into very small and narrow boiling cuts then for each of these cuts (from the same crude the following is true, namely: the relation between the cube root of the absolute temperature in degrees Rankine (°F + 460) of the average boiling point (i.e., the 50 percent point) and the value of the specific gravity at 60° F. is always a constant:

$$K = \frac{\sqrt[3]{T}}{d} \qquad \ldots\ldots(36)$$

where T = middle or average boiling-point in degress Rankine (the absolute Fahrenheit scale) and d = specific gravity at 60° F.

The value of K is 12.2 for Pennsylvania type oils, 11-11.5 for Gulf type oils and 9.8-11.0 for cracked oils. The factor is a measure for the paraffinicity of an oil.

The incorporation of this value into empirical formulae makes possible also to correct for the chemical properties of an oil in evaluating the physical constants; and it is known only too well that the chemical make-up does exert a very great effect on such constants. The accuracy of these formulae is greatly improved, and the range of their useful application greatly enlarged. The values for the paraffins are between 12.2 and 12.9, olefines about 11.5 and for naphthenes at about 11.0.

Fractionation (of course distillation is primarily included) is always carried out at atmospheric pressure when the substance or oil will boil at temperatures where no objectionable cracking takes place; it presupposes also that boiling points are, however, sufficiently high so that the vapors can be cooled to liquid form by normal condenser cooling water, without difficulty even in the warm months of the year.

Distillation at lower pressures, called vacuum distillation, is always employed when the heat sensitivity of the hydrocarbon to be distilled necessitates the need to drop the boiling point below cracking ranges.

Superatmospheric distillation is employed in those cases when the condensation of the distillate vapors at ordinary pressure is impossible as when, for instance, vapor still persists in condensers cooled by ordinary cooling water. The lowest-boiling-point oil

F. Heat Conductivity of Oils

The formula of Cragoe[16] is:

$$\lambda = \frac{0.28}{d}(1 - 0.00054) \times 10^{-3} \qquad \ldots\ldots(37)$$

where λ = thermal conductivity in cm/gm/sec system.
d = specific gravity at 15° C.
t = temperature in °C.

G. Critical Temperature of Oils

The formula of L. C. Roess[17] is:

$$T_k = 202.7 + 1.591\,a - 6.29 \times 10^{-4}(a^2) \qquad \ldots\ldots(38)$$

where T = critical temperature in deg. C.
a = specific gravity at 15° C. multiplied by the arithmetical mean of the temperatures of the 10-, 30-, 50-, 70- and 90-percent point on the ASTM distillation in °F increased by 100:

$$a = d\,(T_m + 100) \qquad \ldots\ldots(39)$$

H. Other Formulae For Molecular Weight

O. C. Bridgeman[18] gives a formula based on specific gravity:

$$M = \frac{d}{1 - d} \times 39 \qquad \ldots\ldots(40)$$

where d = specific gravity at 15° C.

Another similarly based formula is found in the literature[19]:

$$\log M = [2.51 \log(t + 393)] - 4.7523 \qquad \ldots\ldots(41)$$

where t = temp. deg. C.

I. Development and Practical Operation Of Fractionation Plants

The fractionation of petroleum is carried out at various pressures:

1. At atmospheric pressure.
2. At subatmospheric pressure (vacuum).
3. At superatmospheric pressures (pressure distillation).

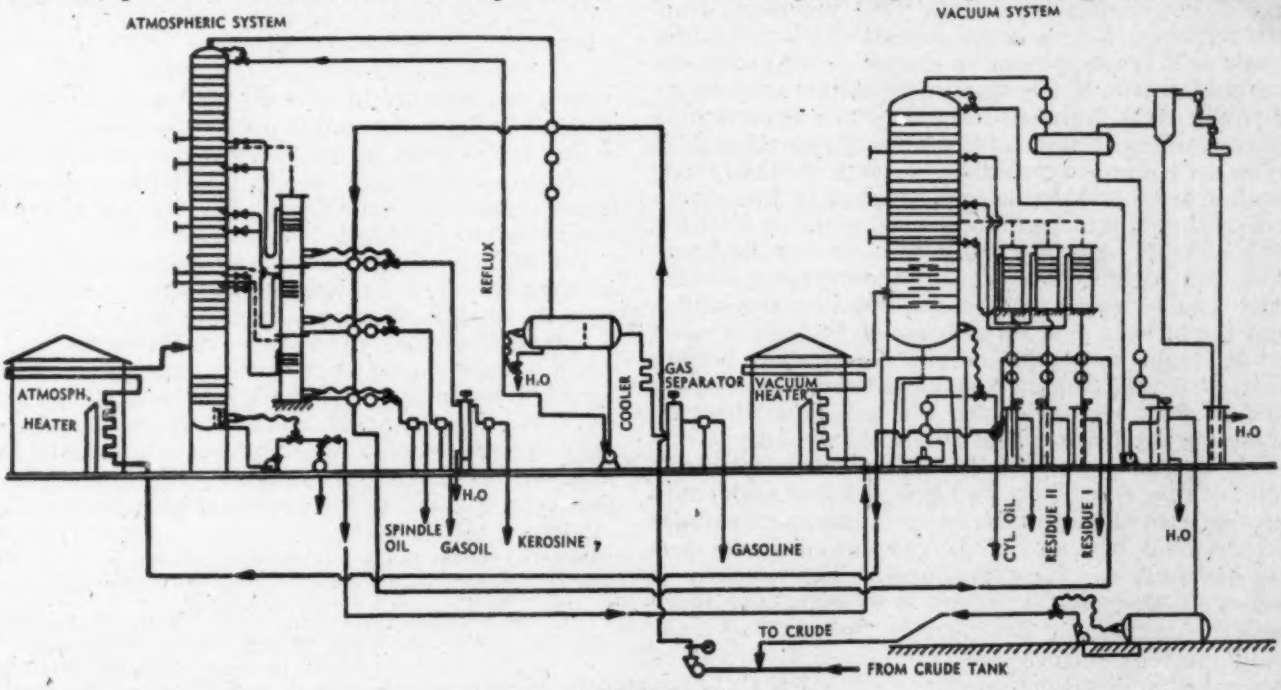


FIGURE 1
Topping and vacuum plant flow sheet

fractions can only be fractionated under pressure, since they exist normally as gases.

Topping distillation belongs to the most commonly carried out straight normal-pressure distillation. By the term is meant the removal of light ends usually up to 320-350° C. The cuts taken are usually: petroleum ethers, rubber solvents, light and normal gasolines, burning oil, gasoil, and at times also a light spindle oil.

Vacuum distillation is nearly always used in manufacturing lubricating oils, and asphalts; and also in rerunning acid-treated cracked gasolines.

In order to stabilize the gasolines and crudes, as well as the removal of benzine from refinery and cracked gases, the cuts or crude is handled by distillation and fractionating under pressure.

Figure 1 shows a diagrammatic flow sheet for a topping-vacuum plant.

The standard equipment for the tower is the usual and much employed bubble-cap fractionation plate. In order to determine the diameter of this tower the amount of mass vapor entering the tower in unit time must be known. This vapor-mass is the combined distillate-vapor and vapors derived from the redistillation of any reflux pumped into the column.

The amount of reflux can hardly be expressed on a molar basis due to the complicated mixture it is and the large number of single components which compose it—in narrow cuts with close boiling point ranges this would be possible. One therefore deals with reflux on a heat-balance basis. This procedure at best is a crude method, and carries no guarantee as would methods giving sharp distinctions or results when the numbers of plates are known in a certain column. Using a heat-balance procedure, the amount of necessary reflux needed is the same, whether low or high limits are set as to the sharpness of the cuts to be obtained.

This reflux quantity is not a numerical figure which can be substituted for minimum reflux, a value which can be calculated on molar basis. Deviations from the latter would be greater the larger the number of single fractions, and the closer their boiling points. In designing new columns this discrepancy must be kept well in mind. We will now illustrate a case for calculating heat-balances:

It is desirable to fractionate (in a column) 10,000 Kgm. of crude per hour (1 Kgm. = 2.2 pounds) into gasoline, kerosine, gasoil and residuum. Percentages of individual cuts are 15 percent gasoline, 15 percent kerosine, and 20 percent gasoil. The quantity of additional vapor due to steam is 30 Kgm. per thousand.

Column temperatures are:

1. Top of column	120° C.
2. Kerosine draw-off	190° C.
3. Gasoil draw-off	260° C.
4. Oil in at	320° C.
5. Bottom	290° C.

In order to simplify the calculation the specific heat (as average) for the oil vapors is 0.55 small cal. per Kgm., and a value of 0.7 is used for the fluid residuum. The value for heat of vaporization is an average figure of 60 small calories per Kgm. In order to secure the above temperature drop and differential in the tower, the following amounts of heat must be withdrawn from the tower:

1. The gasoline vapors must be cooled from 320 to 120° C;
2. The kerosine vapors must be cooled from 320 to 190° C;
3. The gasoil vapors must be cooled from 320 to 260° C;
4. The steam (superheated at 320° C) to be cooled from 320 to 120° C;
5. The fluid residue to be cooled from 320° C. to 290° C;
6 & 7. The gasoil and kerosine must be further cooled as liquids before storage.

The following calculations result:

1.	1500	(320 — 120) 0.55	= 165,000	sm.cal.
2.	1500	(320 — 190) 0.55	= 107,250	sm.cal.
3.	2000	(320 — 260) 0.55	= 66,000	sm.cal.
4.	300	(320 — 120) 0.45	= 27,000	sm.cal.
5.	5000	(320 — 290) 0.70	= 105,000	sm.acl.
6.	1500 × 60		= 90,000	sm.cal.
7.	2000 × 60		= 120,000	sm.cal.
			680,250	sm.cal.

These quantities of heat are taken up by the reflux pumped into the top of the tower; the reflux is mostly vaporized, and its vapors then leave the tower.

We will use gasoline as a reflux; 1 Kgm. of reflux will absorb approximately the following quantity of heat, assuming an initial temperature of 30° C. and a specific heat of 0.6:

1. Heat of liquefaction:	1 (120 — 30) × 0.6 =	45 sm.cal.
2. Heat of vaporization	1 × 60 =	60 sm.cal.
	=	105 sm.cal.

There are 6479 Kgm. reflux per hour necessary to remove 680,250 small calories of heat from the tower. The mean average temperature of the tower where the fractions are enriched is 220° C. The mole weight of the single fractions is:

	Gasoline	120	
	Kerosine	180	
	Gasoil	250	
	Steam	18	
Gasoline and reflux	= 7979 Kgm.	.....	66.5 mols.
Kerosine	= 1500 Kgm.	.....	8.3 mols.
Gasoil	= 2000 Kgm.	.....	8.0 mols.
Steam	= 300 Kgm.	.....	16.7 mols.
			99.5

At a temperature of 220° C., 99.5 mols will occupy a volume of approximately 4000 cubic meters. If the values for velocity of the gases in free or unconfined space (mean free gas velocity) is fairly well established then cross section (and diameter) of the tower can be next calculated.

When the vapors pass through bell or bubble-caps on each tray in the tower the liquid on each plate is sprayed up into the vapor zone in the form of fine droplets. Therefore, the velocity of the vapors in this vapor area must be such so as not to prevent this liquid spray from falling back on the plate by gravity. G. G. Brown and M. Souders[20] present a theoretically derived formula whereby one can calculate the maximum and necessary mass velocity beyond which the spray will not well return to the respective plate:

$$W = C\sqrt{d_2 (d_1 - d_2)} \qquad (42)$$

where W = mass velocity in lb./sq.ft.
d_1 = density of the vapor in lb./cu.ft.
d_2 = density of the liquid in lb./cu.ft.
C = a constant, dependent on the plate characteristics and surface tension of the liquid, and which is experimentally determined.

In the preceding case $d_2 = 0.23$, $d_1 = 43.6$ and C_1 at a separation of plates of 500 mm.$_1$ is equal to 560 when the surface tension of the liquid on the plate is over 20 dynes per cm. Mass velocity W calculates to be 9050 Kgm. per square meter. Since the quantity of vapor is about 12000 Kgm. per hour, a cross-sectional area for the tower of 1.33 square meters is needed. The free space velocity is 0.835 meters per second at free space velocities of 4000 cubic meters per hour. The diameter of the tower therefore is approximately 1300 mm.

The withdrawal of side cuts takes place at a certain plate. One cannot withdraw of course the total liquid on the plate and which flows down from above; a definite portion of it must be allowed to flow down to the plates below. The amount of liquid is designated as internal reflux. The division of the liquid

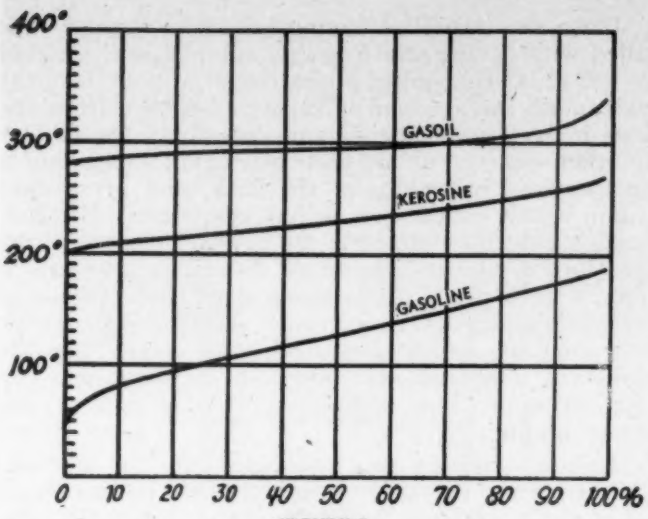


FIGURE 2
Curves of close-cut fractions by topping distillation

stream into external drawoff and internal reflux is carried out in a fairly simple manner; a hand or automatic valve located in the drawoff line is used to regulate the flow by "cracking" or partially opening this valve, until the quantity of drawoff is in line with the desired amount of internal reflux after proper fractionation has been established (desired boiling point of the fraction). This point is recognized when the drawoff shows proper boiling point, or, say, proper flash or color or the like. One admits that this is, indeed, a primitive method; in very recent equipment carefully designed automatic control is used, and reflux can be measured as well as regulated.

The proportioning of these streams should be further discussed. The stream which becomes the drawoff from the drawoff plate is allowed to flow over a weir or special canal opening. As the fluid tumbles over the weir or by its flow through the canal, it is divided into two streams by a removable wall or upright. One part of the stream flows down into the column and becomes internal reflux; the other portion becomes the drawoff stream. The whole arrangement is inside the tower, and the movable upright can be controlled by a spindle or hand valve arrangement passing through the tower wall. With such an arrangement one can maintain the desired ratio of reflux to external drawoff, for instance 3:1; this ratio will maintain itself and is constant, whether the equipment is being pushed or operating at below normal load. The control can also be stopped and started again without interruption of the stream cutting it to slop.

Another possibility to regulate the flow and control of side streams is to arrange an electrically-controlled flow valve in the overhead line which is actuated by a mechanism responding to temperature differences in the takeoff plate; this is truly automatic.

In selecting and producing certain fractions one must remember that in order to obtain good separation, work must be supplied. If the energy supplied to the tower is insufficient for this separation (heat units), the controls or automatic regulators will secure no improvement in close fractionation; in such cases the cuts will continue to come over with poor ASTM boiling ranges; this, in spite of the fact that the correct percent is being obtained. In this case the pipe-coil outlet temperature merely suffices to vaporize the expected amount of distillate. Under such circumstances, the oil temperature must be slowly raised until a satisfactory close boiling point range cut is obtained. The greater the number of desired fractions, and the greater the requirements for sharp fractionation, the greater will be the necessary heat expenditure.

A family of curves showing good fractionation is shown in Figure 2. This separation was made in a pipe-still unit running at 338° C. outlet temperature. At 325° C. one could still detect definite overlapping between the individual cuts, and which stripping through side strippers did not greatly improve.

Side-stripping columns serve to remove light portions (low boiling point) from the side streams—light ends which are impossible to remove in the column itself. Why such light ends happen to be present in an otherwise flat boiling-point curve material can be explained as follows:

Let us assume that a mixture of decane, octane, and pentane is to be fractionated, and that we obtain the decane as residue, the octane as a side cut and pentane as top overhead; the octane comes off at a middle plate and is taken off as a liquid. It is impossible to prevent up-coming pentane vapors from entering this takeoff plate containing liquid octane; the octane is at the temperature of its boiling point. When the pentane vapors pass through, a true or positive equilibrium is established between the two phases; that is, a part of the pentane vapors actually dissolves in the octane, while simultaneously a corresponding portion of octane vaporizes. This octane carried over with the pentane vapor comes back later as internal reflux from the plate above the withdrawal plate. The percentage pentane content in the side stream becomes correspondingly smaller as the amount of reflux increases; however, it will never reach zero. This light or low-boiling-point portion is removed in side strippers by using steam or by a reboiling operation.

The temperature of the octane withdrawal plate is influenced by the pentane content of the octane, since a mixture of pentane and octane begins to boil at a lower temperature than pure octane. This influence is very noticeable in technical units, and the author came to some conclusions in observing one of these units in operation:

An oil was next run containing some 18 percent gasoline, where the temperature of the kerosine drawoff plate was 210° C. Later a crude containing 38 percent gasoline was run through and the kerosine plate showed only a temperature of 194° C. even though the same boiling point of the kerosine was being secured.

American investigators showed that the steam used also exerts a decrease in any boiling point for these various fractions. The author could not verify this, and, theoretically, it is perhaps not probable that the boiling point is greatly influenced by the amount of steam entering the system. Added steam aids evaporation beneficially in a manner similar to when a stream of air evaporates gasoline when passing through the latter—even though the gasoline has not reached the boiling point. American investigators base their viewpoints upon the following:

According to Dalton's law one can, from the vapor composition, calculate the partial pressure with which the single components exert their effect toward producing the total pressure. Also, if a component is present in liquid phase then on equilibrium basis its vapor pressure must be equal to its partial pressure.

Octane boils at 126° C. at 760 mm. pressure. If we now distill octane with steam and if the vapor shows 0.9 mols octane and 0.1 mol water-vapor to be present, then the partial pressure of the octane becomes 684 mm. At 684 mm. octane will boil at 120° C. according to the vapor-pressure curve. If one increases the amount of steam or water vapor, to a ratio now of 0.2 mol water vapor to 0.8 mol octane, then the partial pressure of the octane drops to 608 mm. Hg. At 608 mm. Hg. octane boils at 116° C. If one next raises the ratio to 0.5 mol of steam to 0.5 mol of octane, the new partial pressure of octane becomes now 380 mm. At 380 mm. Hg octane boils at 102° C. Raising the quantity of steam again to 0.8 mol. to every 0.2 mols of octane, the partial pressure of octane becomes now 162 mm. Hg. Its boiling point at this pressure is 77° C. One can continue the calculation at will.

We have thus seen that octane actually boils at 77° C. in the presence of steam at the ratio of 0.8 mol steam to 0.2 mols octane; but in order to have this vapor begin to condense and to obtain it as a liquid, a slight drop in temperature must be obtained, say down to about 76.8° C. Let us next heat this same condensate just obtained, which is composed of 0.8 mols of water and 0.2 mols octane, again to 77°C. It would then again come to boiling and convert itself tc vapor.

The previously described mixtures also can be subjected to the same procedure, and by doing so we arrive at the following extraordinary situation:

(1) 0.1 mol H_2O and 0.9 mol octane boils at 120° C.
(2) 0.2 mol H_2O and 0.8 mol octane boils at 116° C.
(3) 0.5 mol H_2O and 0.5 mol octane boils at 102° C.
(4) 0.8 mol H_2O and 0.2 mol octane boils at 77° C.

Such a phenomena has never been observed. A mixture of two immiscible fluids, as octane and water, will boil when the sum of the vapor pressures of the components equals the total pressure on the mixture, namely, 760 mm., or slightly above the 760 mm. pressure. The quantitative relative amounts of substance of the two immiscible liquids affects neither the boiling point temperature nor the vapor composition. Both remain constant during the whole course of the distillation, and just so long as both liquid phases are present as such. The use of steam in crude-oil distillation proceeds under difficult conditions. With crude oil, dry steam is injected into highly heated oil (200-400° C.). The temperature range is therefore so high that water is not present as a liquid, since its vapor is actually superheated in this temperature range. The behavior of the steam here is that of an inert gas, insoluble in the oil. Vaporization is therefore clearly enhanced in that manner, and the vapor composition can be calculated according to Dalton's law. It is almost incorrect to draw from this the conclusion that the boiling point of the oil is lowered in proportion to the amount of steam used. Any fluid can evaporate without also necessarily boiling.

How are these contradictions to be cleared up? The explanation is easy to find when one bears in mind what American technologists have to say concerning practical distillation procedure: In a very well known treatise one reads: "The steam need not be bubbled through the oil although no harm results by doing so." That means then just to pass the steam or the inert gas over the surface of the oil to be distilled, and that this is sufficient to obtain the desired effect.

If we now visualize having before us a small flask filled with octane standing in a cabinet or chest held at 20° C., at the end of a quarter of an hour we next determine the amount of vaporized octane from the loss in weight of the octane vessel. At the end of another quarter of an hour we again determine a further loss in weight of the flask, and prove that again a part of the octane has evaporated. By Dalton's law we can calcultae the partial pressure of the gasoline vapor, and therefore the vapor pressure of fluid octane, from the volume of air and volume of octane vapor. We then would validate the strange fact that the vapor pressure of the octane (despite constant temperature) shows an increase in every quarter hour. The explanation in this case is also quite simple.

Dalton's rule in this case can only be properly applied when the air is saturated with octane vapor at a given pressure and temperature. Actually, the vapor pressure of the octane does not rise or increase, but incidentally, the degree of saturation of the air with octane vapor.

In the case of the distillation of gasoil, knowing that the partial pressure of the gasoil vapor in the mixture of water vapor and gasoil vapor decreases with increase in the amount of steam, then we also find that it is not the vapor pressure of the gasoil that has dropped but the saturation point of the steam with gasoil vapors. For causes of saturation, the partial pressure of the gasoil must remain constant, as the vapor pressure of the gasoil also remains constant at steady and constant temperature and pressure.

It is not affected by the quantity of steam. Were the theory of the American investigator valid, then the boiling point of water would be dependent on the humidity of the air; for instance, at low humidity, where the partial pressure of water vapor in the air is small, water would be compelled to boil below 20° C. at air temperature of 20° C., while on a rainy day it would boil at 20° C. The error is seen to be in neglecting to take into account the concept of saturation, and also confusing the idea between boiling and vaporization.

The currently common viewpoint that the addition of certain amounts of steam will lower the boiling point of an oil to a definite and calculable degree equivalent to boiling the oil at certain low pressures (vacuum) is plainly incorrect.

As we have seen, the capacity of a column is defined by the quantity of vapors passing through it. It can also be defined by the charge of true liquid it can handle. In the case of many columns one can determine that the fluid capacity or load ranges occurs in much more narrow limits than does the vapor charge. One reason usually is that the rundown lines are of insufficient diameter. Plates and vapor lines and rundown lines usually are made of cast iron. Since such materials are easily cast, etc., it is common practice to construct such lines of tubular goods.

The performance of rundown lines is not a matter of cross section but is dependent on the quantity of liquid entering or being charged to the line. The charging capacity or carrying capacity of a rundown line is dependent on its circumference, since this determines whether the liquid charge will flow freely or become choked. The relation circumference-to-cross section is in this respect untrustworthy or of no value in the case of circular cross sections; in addition, circular rundown lines are usually so used and placed in congested parts of a plant and it has been

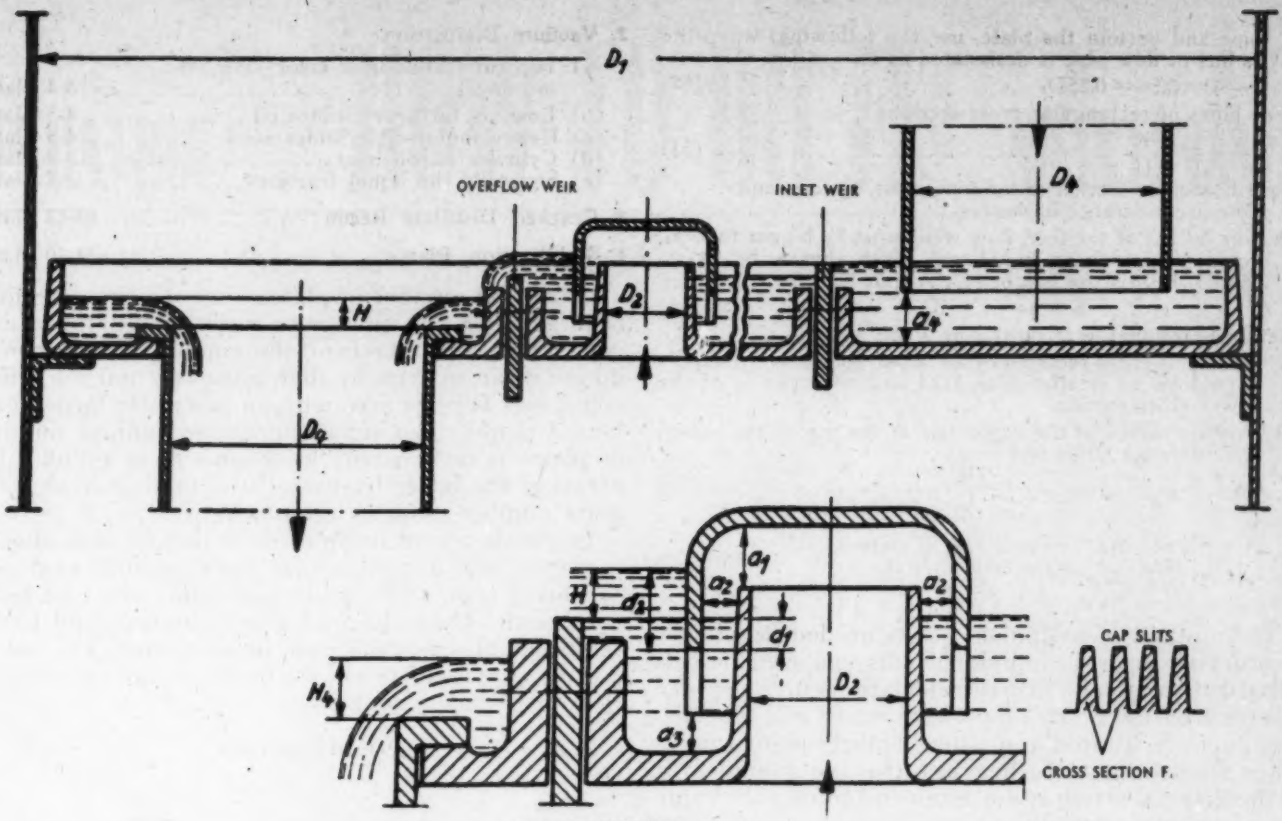


FIGURE 3
Section through fractionating plate

the habit therefore to use pipe of smaller cross section than is called for. This is especially evident in the case of columns where the liquid charge is quite high in relation to its vapor capacity. Columns of this type are those used in stabilizing and in the natural gas industry; rundown lines must be carefully considered as to gravity and unimpeded flow of vapors and liquid.

The resistance offered to the flow of vapors passing through a plate is composed of:

1. The static liquid seal; that is, the height from the upper edge of the vapor flow pipe (or the slit in the bell-cap) to top of the overflow weir in mm. of liquid.
2. Height of liquid level over the top edge of the weir in mm. of liquid.
3. Frictional resistance of vapors passing through the vapor-pipe, bell-caps or other caps, and through the slits, etc., in mm. or liquid.

Friction loss is calculated by the Brown and Souders formula[20]:

$$H = 0.65 \frac{d_s}{d_l} V \quad \ldots\ldots (43)$$

where,

H = frictional resistance in inches of liquid
d_s = density of the vapors
d_l = density of the liquid
v = vapor velocity in vapor pipes.

This formula is adaptable to normal practice for bell-caps with circular cross section.

Figure 3 shows cross section of a bell-cap plate and bubble-cap. To calculate further we have the following:

1. For the diameter of the caps 2R, we find this equation satisfactory, using 2r as the diameter of the vapor pipe D-2, we have:
$R = \sqrt{2}\,(r + \text{wall thickness})^2$ ..... (44)

2. For the distance a — 1 between upper edge of vapor pipe and undersurface of the bubble cap, there is:
$a - 1 = 0.8r$ ..... (45)

3. The sum of the surfaces of the cap slits are:
$F = 1.8r^2\pi = 5.65\,r^2$ ..... (46)

4. The overflow weir should be long enough so that the rise of the liquid level over the top edge of the slits is not over 37 mm. "Hold-back" height H can be calculated by Francis' formula:

$$V = 1.83L\,H^{3/2} \quad \ldots\ldots (47)$$

where,

L = the length of the weir in meters
H = "hold-back height" in meters
V = liquid volume in cu.meters/second.

5. The drain pipe D should have dimensions so that value for H is not greater than the height of the overflow weir. For the height of flow or H, Brown and Souders (20) give:

$$Q = 0.021\,D\,(H)^{1.5} \quad \ldots\ldots (48)$$

where,

Q = liquid in cu.ft./sec.
D = diameter in inches
H = height of overflow in inches.

When the quantity of liquid is expressed in cubic meters per second, and D and H in cm., the formula can be written:

$$Q = \frac{0.084\,D(0.4H)^{1.5}}{35.3} \quad \ldots\ldots (49)$$

6. For a drain-pipe of rectangular cross-section, these authors give:

$$0.008\,A\,H^{0.5} \quad \ldots\ldots (50)$$

A = Cross-sectional area in sq. inches. Expressing A in square meters A then becomes 10.76A.

In the metric system one then obtains:

$$Q = \frac{0.008\,(10.76A)\,(0.4H)^{0.5}}{35.3} \quad \ldots\ldots (51)$$

7. For the distance a — 4 between the lower edge of flow

pipe and bottom the plate, use the following, when the radius of flow pipe is designated as r:

$$a-4=0.5r=0.25D_4 \quad \ldots\ldots(52)$$

For pipes of rectangular cross-section:

$$a-4=\frac{F}{U} \quad \ldots\ldots(53)$$

where F = cross-section of the pipe in sq. meters, and U = circumference in meters.

8. The height of the feed flow weir must be bigger than a_4, since a permanent liquid-seal must always be maintained. If S is the height of the weir then:

$$S=a-4+K \quad \ldots\ldots(54)$$

wherein K is equal to at most 2 or 3 cm.

9. The total cross-sections of all vapor spaces or chambers should be no smaller than 1/14 and not over ⅛ of the tower cross section.

10. For the radius of the vapor line at the top of the tower, the following holds true:

$$r=\frac{R}{C} \quad \ldots\ldots(55)$$

where,

r = rad. of vapor line in meters,
R = rad. of tower in meters
C = 3.75

The number of individual plates needed in a tower in order to separate individual cuts can well be calculated theoretically; these calculations become very complicated for crude oils where many wide or narrow cuts are wanted and where boiling point ranges differ from lightest to heaviest (in one column); it is therefore the rule quite often to obtain this value by pilot-plant determinations in advance of constructing the final tower. However, there have been established from practice and by calculation, the following rules for plates:

1. Topping Distillation:

(a) Separation of light and heavy naphthas.....6-8 plates
(b) Separation between heavy naphtha and kerosine .....5-6 plates
(c) Separation between kerosine-gasoil.....4-7 plates
(d) Separation between gasoil and oil inlet.....3-4 plates
(e) Stripping residue with direct steam.....4-6 plates
(f) Stripping of side cuts with direct steam.....4-5 plates
(g) Separating gasoil and spindle oil.....4-5 plates
(should be a spindle cut be taken off the atm. tower.)

2. Vacuum Distillation:

(a) Top cut (off-odor or color)/low vis. motor-oil .....3-4 plates
(b) Low vis. oil/heavy motor oil .....4-5 plates
(c) Heavy motor-oil/cylinder stock .....4-5 plates
(d) Cylinder oil/oil inlet.....3-4 plates
(e) Stripping the liquid fractions.....3-4 plates

3. Cracked Distillate Rerun.....10-12 plates

4. Stabilization Plants.....24-40 plates

When the number of plates between two fractions is large, then the energy or work of separation becomes less, and therefore, the amount of reflux. We do not mean to state by that, however, that the reflux could ever become zero with an extremely large number of plates. The reflux needed at infinite number of plates is designated "least amount of reflux." Increasing the latter by very little, then the value for plate number assumes a finite figure.

In the design of technical installations it is always a matter and a compromise between first cost and operating cost, and a general average must be reckoned with. The values for plate numbers and tower requirements take this rule into account. The calculations are practical and are based on the experiences in actual refinery practice.

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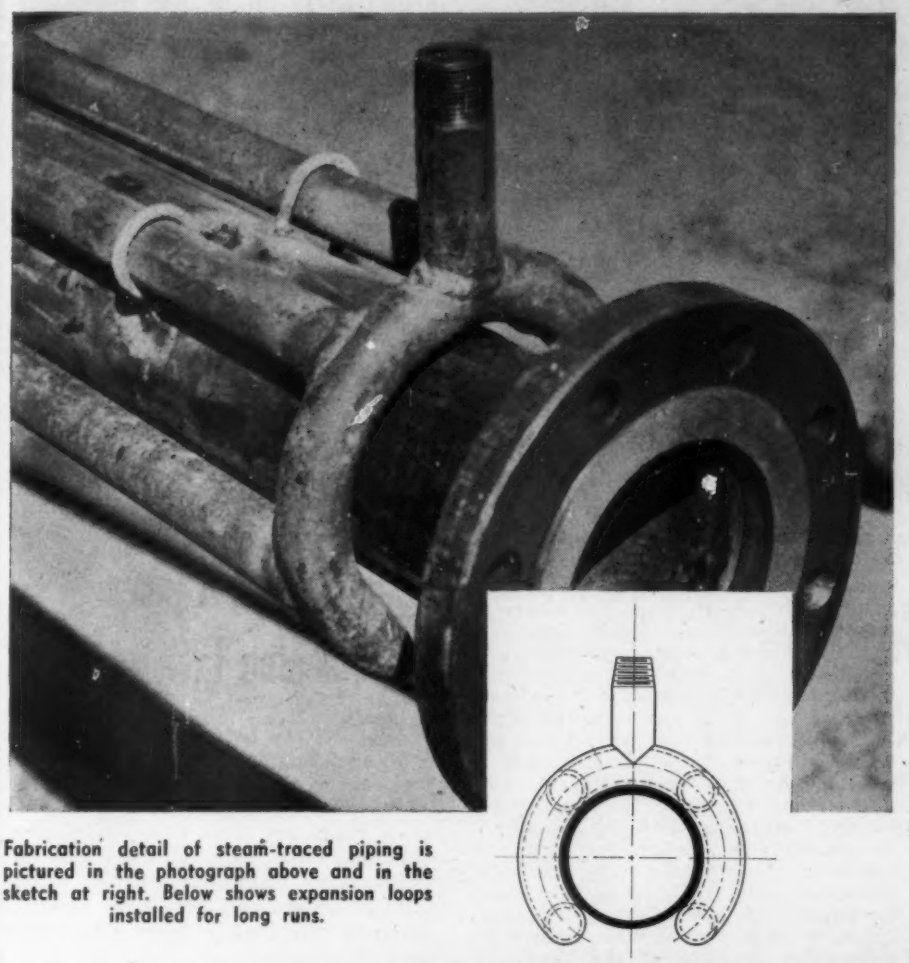
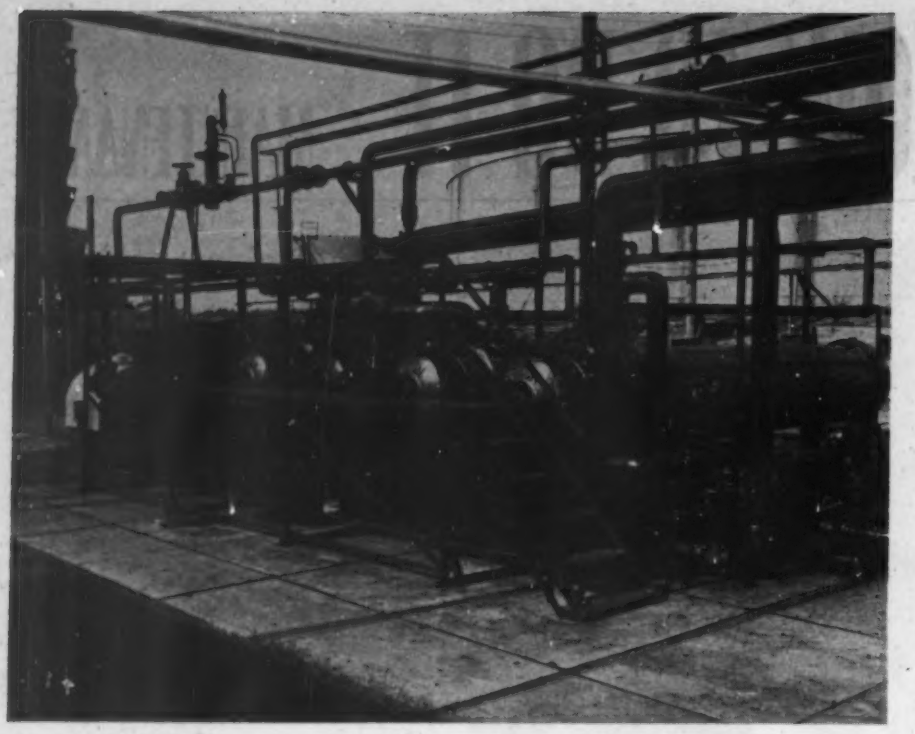


Fabrication detail of steam-traced piping is pictured in the photograph above and in the sketch at right. Below shows expansion loops installed for long runs.

Steam Tracing of Lines For Viscous Fluids

WHERE very viscous materials or extreme cold weather may cause process or transfer pipe lines to plug, it is customary to heat the lines with steam to maintain viscosities which will permit satisfactory fluid flow. Several piping arrangements are possible. Steam-jacketed piping is excellent in heat-transfer efficiency but is costly and may require packed expansion-joints where long runs are involved, and while a small steam line placed inside the viscous fluid line is often used the method is subject to severe maintenance problems; with either arrangement leakage of steam into the oil may become a major nuisance as the cause of emulsions and tank-foaming, and when leaks occur they are difficult to locate.

Talco Asphalt and Refining Division of American Liberty Oil Company in its plant at Mount Pleasant, Texas, has installed steam-heated lines which are free from the principal objections of the usual methods. The viscous material is carried in a center pipe of suitable diameter and this pipe is heated by a cluster of four or more small steam pipes which are arranged uniformly around the center pipe. The steam pipes are connected in parallel and are held to the center pipe by small welded U-bolts. The steam pipes and the center pipe are free to contract or expand with relation to each other on temperature changes. Where flanges or valves occur in the



Platform provides access to instruments, and can be moved to service exchangers.

main line, the steam pipe headers are connected with expansion bends which jump over the obstructions, and for short pipe runs no other provision for expansion of the steam piping is necessary. Where long runs of piping occur, the greater expansion of the steam piping is absorbed by special expansion loops which are located at suitable intervals in these small lines. All steam-traced lines are thoroughly insulated.

Special Truck Facilitates Exchanger Bundle Handling

TUBE bundles of heat exchangers are expensive. So one company provides special transportation for them when it is necessary to remove them and ship them to the repair shop. The means of transportation is by a low, flat-bed trailer. The wheels are mounted directly under the frame, with the rear wheels having separate spindles for axles. Front wheels have a solid axle on a fifth wheel for guiding when towed behind a service truck. The bed is substantially made of wood planks upon the steel frame, having cradles crosswise to support the bundle. Depending upon the diameter of the bundle, is a provision for extra blocking beneath the tube separator rings, and the truck is provided with hooks on each side to attach a boomer chain. If only one bundle requires retubing for the moment, the bundle remains upon the trailer until completed after which it is towed back to the shell for replacement.

Exchanger tube bundles are moved safely by this truck.

Valve for Draining Gate Valve in Water Service

AS LONG as water is flowing through a gate valve there is little danger of freezing, but when the valve is not in use the pocket of water trapped in the valve in the dead spaces around the gate and in the bonnet are likely to freeze in cold weather and damage the valve body. C. G. Rook, Jr., Water Chemist, Talco Asphalt and Refining Division, American Liberty Oil Company, Mt. Pleasant, Texas, reports that his company, after having trouble with several gate valves which were cracked by freezing, have now provided drains for valves on water lines. The bottom of each valve body was drilled and tapped for a quarter-inch pipe nipple fitted with a quarter-inch brass globe valve. When valves are not in use these bleeder valves are opened to drain the valve bodies, eliminating danger of freezing and damage.

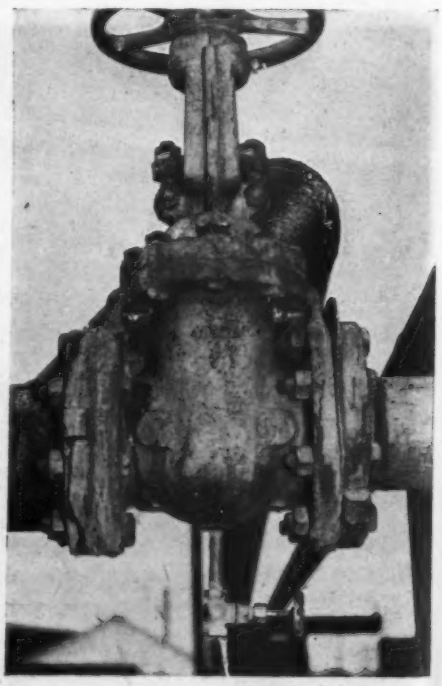
Sturdy Operating Platform Light Weight and Movable

EXCHANGER banks arranged for multi-purpose use in heat transfer between hot product streams and cold feed streams may have complex valve manifolds. Often some of the valves are located in inaccessible positions where it is also difficult to install permanent operating platforms without interfering with the tube-bundle clearances required whenever exchanger inspection and repair work is to be performed.

One refinery has met such a condition in its plant by means of a special lightweight movable steel platform and stairway. As shown in the photograph the platform provides easy access to all the valves above the exchangers at their channel ends, but when necessary the whole platform structure can be moved aside giving full clearance for tube bundle pulling or other exchanger repair work.

Slice Bars or Lances For Cleaning Exchangers

CLEANING between tubes in heat exchanger bundles is at best a difficult job, but foreign matter must be removed if the efficiency of the unit is to be kept at its maximum. Thin knives of flexible steel sometimes are used, but Union Oil Company of California provides equipment which not only breaks the accumulation of coke, mud or dried sludge from



Small valve below drains water from the large valve to prevent freezing.

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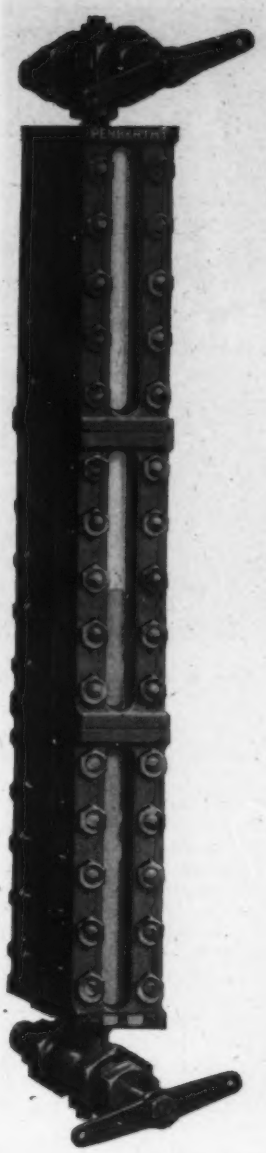

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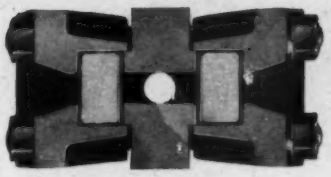

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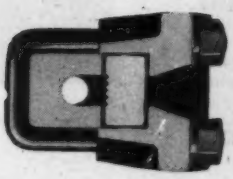

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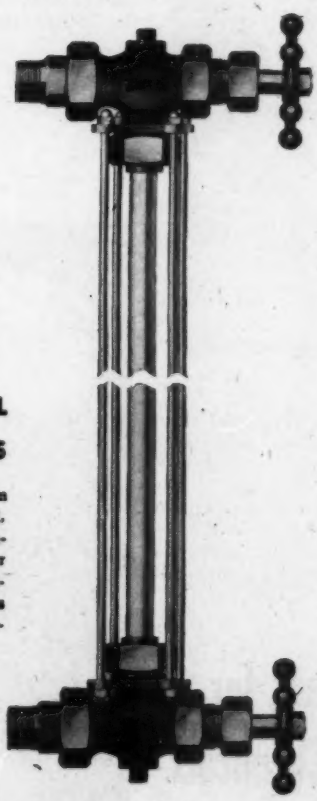

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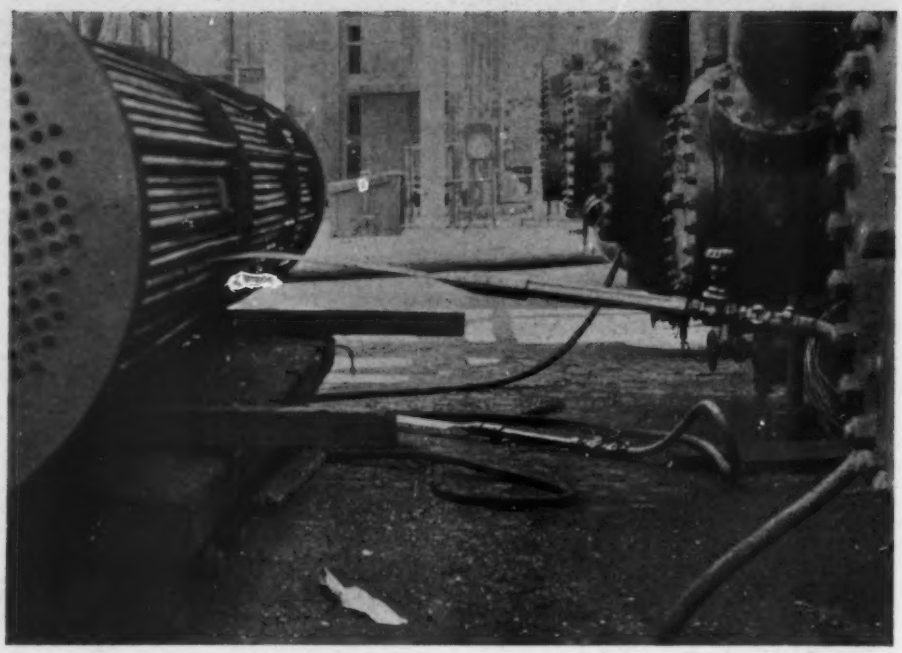
the tube outer surface, but can be used with air, water or both, under pressure.

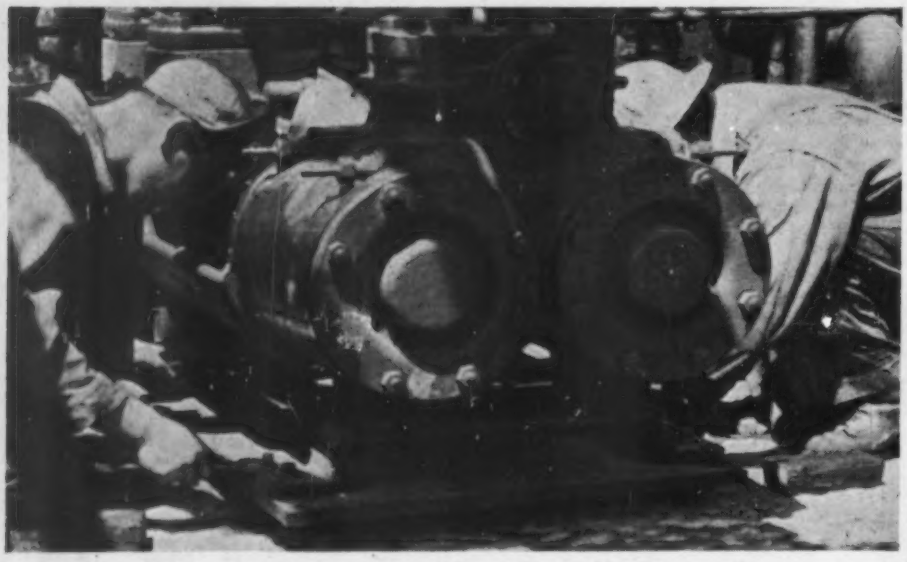
These lances are made of steel tubing, flattened as thin as possible without closing the inside. The ends are rounded and beveled so they will pass between rows of tubes without hanging up or cutting into the tubes. Fittings are furnished which connect to air or water hose, having a control gate valve so the operator can gauge the stream of air or water, as the case may be. When cleaning a tube bundle, the assembly usually is mounted upon a flat bed, low wheel truck, and the bundle itself turned on the supporting cradles at an angle which will allow the lance to be used comfortably while slicing between several rows.



Water or air pressure is introduced through flattened tube when scale is being cleaned from outside of exchanger tubes.

Bolts Level Equipment On Concrete Foundation

LEVELING of heavy equipment after being placed on the concrete foundation has been done by the conventional method of blocks and tapered steel wedges. Wedges, however, are subject to slight compression, and must be driven by experienced men to obtain perfect setting. One company has developed a different system which is both simple and effective. The block is formed with foundation bolts set into the form as is cutomary. Before the bolts are hung onto the template, threads are run down much farther than formerly, so that nuts may be run down to the top of the foundation. When everything is made ready for the pump, for example, nuts are threaded onto the foundation bolts to a point where adequate grouting can be conveniently done. The pump is then set on bolts, resting, however, upon the nuts on the foundation bolts. A four-point suspension is presented for leveling so that threading one nut down a trifle, another up slightly places the bedplate level. Top nuts are threaded down tightly and leveling checked again. If the unit shows no change, grouting is done by using expanding cement mixture of a 1-1-1 by volume.



Accurate leveling of pumps, engines and motors can be accomplished by manipulating bolts on studs which anchor the equipment to the concrete base.

The advantage of this method over the wedge type leveling is obvious. Sledging of wedges is eliminated, where a misplaced blow can crack a bedplate. Unskilled workmen can level the unit with end wrenches. Nuts do not slip, as wedges do, and the nuts assist in supporting the unit along with the concrete grout.

Simple Arrangement for Metering Water Chemicals

WHERE chemical treatment is used to maintain satisfactory cooling water conditions the chemicals are often mixed into concentrated solutions and injected into the stream by means of special metering and pumping equipment, so that the use of chemicals can be accurately controlled.

One refinery superintendent has devised a simple means for adding chemicals to cooling water which accomplishes the desired results without the use of expensive special equipment. As shown in the photograph, a steel drum is used to hold treating solution. An open drain line from the bottom of the drum discharges treating solution into the cooling water sump from which the water circulation pumps take suction. The drum is closed from the atmosphere except for the drain line and an air inlet at the top. Flow of solution from the drum is controlled by a valve in the air inlet line.

In setting the system up, the required

Air intake, controlled by the valve on top of barrel, regulates flow of chemical into cooling water stream.

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Elliott cutter heads, constructed of tough alloy steel, are built for long, arduous, heavy-duty service, too. Their heat-treated cutters won't dull up until a whole string of meritorious service stripes have been won. Moreover, these cutter heads are tuned to work with the powerful Lagonda 1100 Series motor—no other head will stand up and operate so harmoniously with this extra-powered motor.

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weight of chemicals for a 24-hour period was mixed with enough water to fill the drum, the solution was placed in the drum, and the air valve was set, by trial and error adjustment, so that the drum would be almost empty after 24 hours. The drum is refilled each morning.

Ordinarily, the air valve requires little adjustment, but when a change is necessary the correct setting is judged by noting the time required to fill a small graduated bottle when the drum is full. As the drum empties, the rate of flow of the solution of course changes, but the chemicals are well mixed into the total cooling water and the system has proved satisfactory in operation.

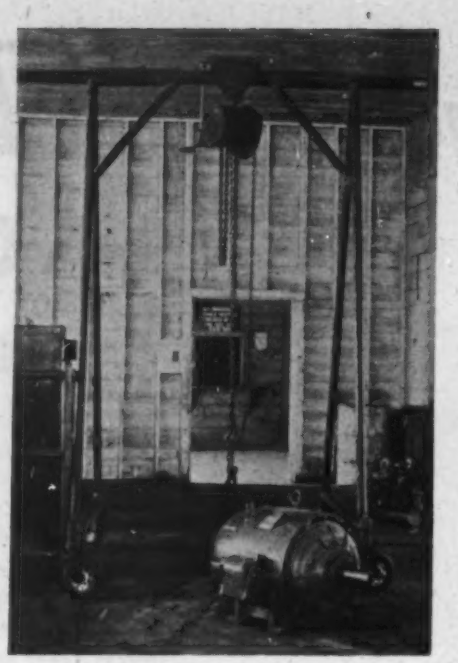
A similar arrangement using an open drum with a valve in the solution drain line was not satisfactory because the valve plugged and the rate of chemical addition could not be controlled without frequent adjustment.

Adjustable A Frame Light, Strong, Readily Movable

A FRAMES for hoisting heavy equipment ordinarily are fabricated as a solid unit, and must be moved about as such. One which may be knocked down and moved in sections is just as easily made, is more convenient to handle, and has the advantage of adjustable over-head-trolley length.

The frame sides are constructed as usual, but in place of a cross bar connecting them, each end piece is topped with a short section of pipe which is welded and braced for ample strength. When set up for use the two sections are connected by a smaller pipe run through the pipe on either end. This connecting pipe may be of length to suit the spread desired between the two ends of the frame.

The trolley in use with the frame described has rollers shaped on a lathe from bar steel, and is mounted on a shaft with roller bearings so the trolley



This A frame is in three sections—the cross bar is a pipe within pipes at each end, making it adjustable as to spread.

may be moved back and forth without great effort.

The assembly is supported on small rubber-tired wheels with swivel settings in ball bearings, so the unit moves easily over the shop floor.

Rack Makes Right Gasket Quickly Available

WHEN overhauling a plant, new gaskets can be selected as needed with greater speed and accuracy when they are racked for size and composition. A convenient rack costs little to build. It is made in the same form as a carpenter's saw-horse, only higher; the height can be varied to suit the individual requirements of the plant repair man or the chief engineer in charge. These racks contain a number of quarter-inch pins, made of welding rod or other material which may easily be obtained, and driven into holes bored for the purpose. Gaskets may be slipped over the hangers in sequence, smallest at one end, gradually larger to the other, or, to suit the fancy of the men who use it.

This rack makes securing the proper gasket an easy matter.

Flywheel Cover Has Door For Use When Starting

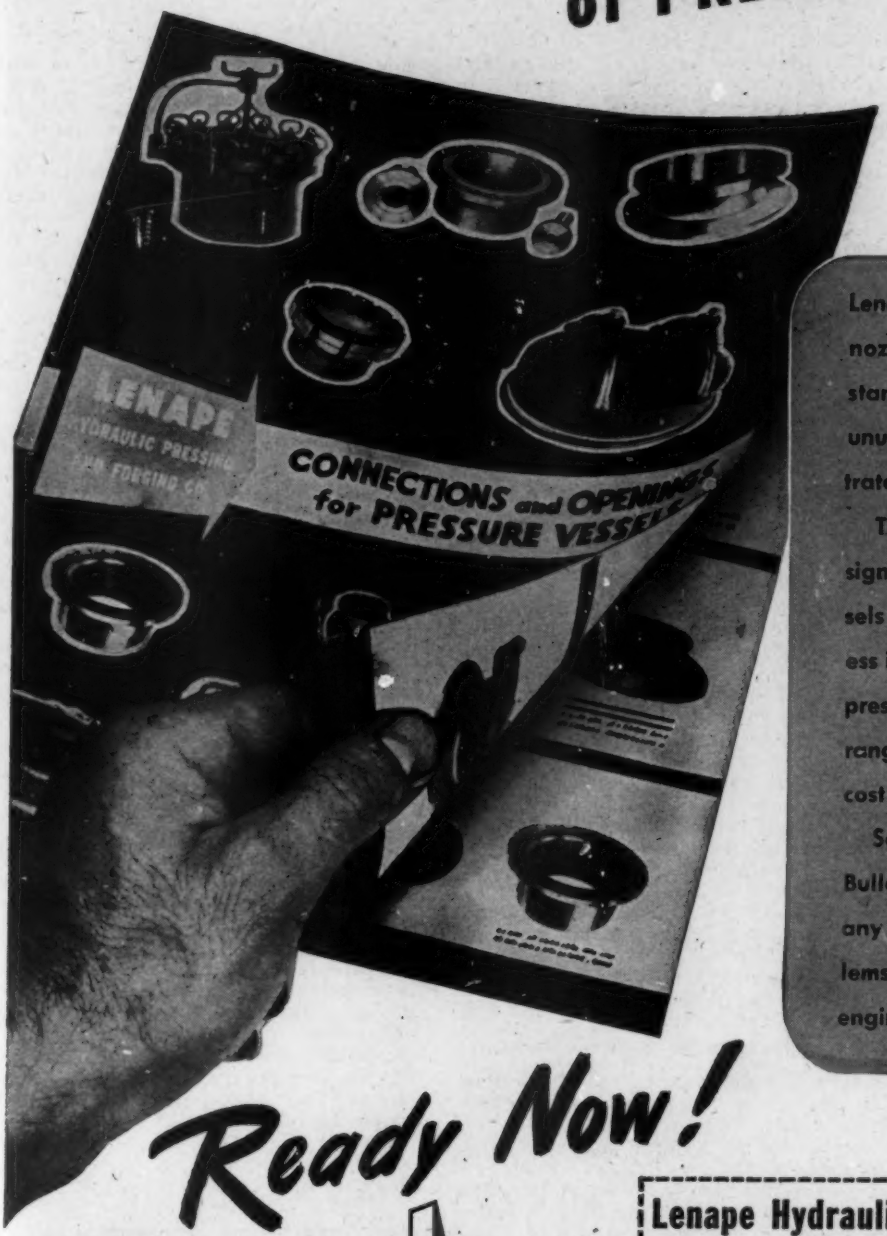
FLYWHEEL covers on engines in a gasoline plant in Kansas serve a double purpose. The covers are shaped from sheet steel attached to sturdy angle-iron frames which set directly upon the concrete floor of the building. Men working on engines when running are protected when inspecting bearings and sight-feed oilers. The other purpose is obtained by placing a small window at the logical point so that the engineer or oiler can use a jack to spot the engine for starting without removing the cover. Window is cut after forming the cover, and hinges attached for swinging, with hasp and staple for locking.

The window in the flywheel cover is for use when engins is spotted for starting.

Steel Wire Beats Twine For Foundation Markers

WHEN concrete foundations and similar works are laid out in many plants it is customary to use heavy cotton twine, sometimes called "chalk line," to establish boundary lines and other important dimensions. Whenever the work is complex so that the layout lines will be used for several days, or where high accuracy is required, better results can be obtained by the use of mild steel wire of about 18 or 20 gauge. Steel wire is strong so that it can be stretched taut and is not affected by atmospheric humidity.

HELP FOR DESIGNERS and FABRICATORS of PRESSURE VESSELS



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Veterans' Reemployment Rights

HAROLD J. ASHE

THE whole context of the statute (Section 8, The Selective Service and Training Act) and the purpose for which it became the law was to minimize, insofar as possible, the sacrifices of those who were required to enter the military service by assuring them their jobs, their pay and their status with their employers would be inviolate and secured to them in order that they might return to the status quo if they made application. . . . " *Judge Mac Swinford, United States District Court, Eastern District of Kentucky, in the case of Robert E. Hall v. The Union Light, Heat and Power Company, etc. (53 Fed. Supp. 817).*

With the demobilization of millions of service men and women, employers are in some cases confronted with a serious reemployment problem, and one which calls for the most thorough understanding of the law as it applies to veterans' job rights. A very large percentage of returning veterans have prior claims to their old jobs as a legal right established by the Selective Service and Training Act.

Super-Seniority

The United States Supreme Court has ruled that World War II veterans do not have claims to jobs superior to those of non-veterans. This is contrary to a position taken by Selective Service which had insisted that for a period of one year from the date of reemployment veterans had, as a right conferred by Congress, an absolute right to their jobs, irrespective of seniority held by non-veterans. However, employers should not be hasty in jumping to conclusions.

Gist of the decision is this: Veterans' seniority involves not only the time worked prior to entering service, but his time in service, as well. That is military service is treated as though he were on leave of absence. His seniority continues to accrue for the period of his military service, but it does not increase beyond this point.

Example: Veteran worked three years in plant before entering service, served three years in the armed forces. Total seniority is six years. He could "bump" non-veteran with five years service, but not displace non-veteran with more than six years service.

Meantime, many employers have followed Selective Service interpretations and face possible liability because of the Supreme Court decision. They are concerned lest other Selective Service rules and interpretations may be ruled adversely by the highest court.

Recognizing the unfair position that employers find themselves in, where they may be damned if they do, and damned if they don't, a bill (HR 6035) has been introduced in Congress. This measure is intended to relieve such employers of liability where they have acted in good faith, and have relied on rulings and interpretations of Selective Service in respect to reemployment of veterans, or of courts or arbitrators, where such rules and interpretations have been later amended, rescinded or reversed.

Conditions for Restoration

Originally it was implied that a veteran could not be forced to join a union as a condition of reemployment. Now this is stated categorically. "The only conditions for reinstatement that a veteran may be required to meet are those conditions which are specifically enumerated in the law. Union membership or other conditions not enumerated in the law may not, therefore, be required of a veteran as a pre-requisite to his reinstatement." So decreed one judge. That an employer may have a closed-shop agreement with a union does not alter the veteran's right to his old job without carrying a union card.

Veterans do not lose reemployment rights because they have signed "quit slips" or "resignations" at the time they entered the armed forces. Neither does a lapse of time between leaving employment and entering the armed forces defeat the veteran's right to reinstatement, providing such lapse was reasonable or due to necessity to prepare for the change from civil to military life. However, the veteran must have left that position in order to enter the armed forces. Entrance into the armed forces must have been the purpose, object and primary cause for leaving employment. A veteran who quit a job for reasons not related to military service, and then, later, entered the armed forces, has no statutory rights in his former job.

Application for Reemployment

The fact that an employer has offered to reinstate a veteran in his former position within the prescribed 90-day period, but before the veteran has applied for reinstatement, does not affect the veteran's right to apply for reinstatement at a later time within the 90-day period. —(*Grasso v. Crowhurst et al.*)

Hospitalization After Discharge

Where a veteran's condition at time of release from active military service requires hospitalization—and he is hospitalized—the 90-day period for application for reemployment is held in abeyance until the date he is relieved from hospitalization, provided hospitalization does not exceed one year. If it exceeds one year, reemployment rights expire after 90-days following one year of hospitalization.

Hospitalization must take place immediately following release from service. "Immediate" must be reasonably construed to allow a period necessary to make arrangements and get to the hospital. The hospital may be either government or private and he may transfer from one to another and his status as hospitalized is not terminated by short interruptions in hospitalization. His status as a hospital patient terminates on the date of his discharge by hospital authorities, even though he may be required to return periodically for observation.

Temporary Position

The only positions not covered by the law are "temporary" positions, and it is on this point of definition that much disagreement arises between employers and veterans. By using the phrase "position other than temporary" Congress evidenced an intention of using a broader concept than would have been entailed by use of the word "permanent." Hence, before a veteran is deprived of his reemployment rights, it must be shown clearly that the employment he left to enter the armed forces was "temporary." Borderline cases should be resolved in favor of the veteran, and courts are taking this position.

Persons Who Left the Same Job Assignment

Originally, the interpretation was given that where several successive employes held the same job assignment and each successively left for military service, such job claim was held only by the first employe to enter the military service. A more liberal view now prevails judicially. The fact that several veterans left the same job assignment in a employer's establishment to enter the armed forces is not determinative of whether the "position in the employ of" the employer which any of such veterans left was temporary or other than temporary. It is the character of the employment relationship that should govern and not merely the particular assignment being carried out at the time of entry into active military service.

Part-Time Employment

Part-time employment is not necessarily synonymous with temporary employment. The question of whether a position is temporary or not cannot be resolved solely on the basis of the number of hours of work per day or per week. If the part-time work is not short term, but involves the performance of regular continuing service for an indefinite period, it is not a temporary position.

Probationary Workers

A veteran may have been a probationary worker and still have reemployment rights. "Probationary" does not determine whether his position is temporary

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or otherwise. This may be determined only on the character of the employment relationship and circumstances surrounding it. A probationary worker is not to be considered a temporary worker when the term "probationary" is used only to indicate a period of time which must elapse before certain privileges become available to the worker, such as seniority rights, resort to employer-employe appeal procedures, vacation and insurance benefits or automatic pay increases and promotions.

Apprentices—Trainees

Neither are the terms "apprentice" nor "trainee" determinative of the question whether the position is temporary or otherwise. A person may be an apprentice, a trainee, a helper, a journeyman, and still be either a temporary or other than temporary employe, depending upon the terms and purposes of the employment relationship.

Capacity to Perform the Job

Veterans find themselves, in countless cases, in competition for jobs with persons who have been filling them in their absence. One judge pointed out that "handicapped as they are bound to be by prolonged absence, such competition is not part of a fair and just system, and the intention was to eliminate it as far as reasonably possible." When reemployment is effected, the veteran may require a period of time to re-acquire skills. That is a reasonable and necessary incident to reemployment normally required for a person to become proficient in the work.—(*Kay v. General Cable Corp.*)

If the veteran can do his job or can be retrained on the job to perform the duties safely and with acceptable efficiency within a reasonable period, he is entitled to be restored to that job. The veteran is entitled to every practical opportunity to prove that he can perform the duties of the job.

Medical Examination

If the veteran's condition is such as to raise a reasonable doubt in the employer's mind regarding the veteran's ability to perform the duties of his former position, or when it is the established practice of the employer to give a medical examination to all employes returning from furlough or leave of absence, the employer may require a medical examination without expense to the veteran. The determination made upon such medical examination, however, is not binding upon the veteran and does not deprive him of any legal remedies to which he is entitled under the law.

No veteran with reemployment rights may be denied his former position or one of like seniority, status and pay, on the basis of disability except where one or other of the following situations exist:

(a) His disability is such as to make performance of duty impossible or to reduce his job efficiency to a level below that normally expected of an acceptable employe; or

(b) His presence on the job would jeopardize the safety or health of himself or others.

Impossible or Unreasonable to Reinstate

While the law provides that an employer does not need to reemploy a veteran if to do so is impossible or unreasonable, this is a question of fact to be determined in the light of circumstances surrounding each individual case.

"Unreasonable" means more than inconvenient or undesirable to the employer. The veteran must be restored to his position even though he has been replaced by a substitute who has been able, either by greater efficiency or a more acceptable personality, to make it more desirable for the employer to retain the substitute instead of reemploying the veteran. The fact that there would be the loss of efficiency and possibly some additional expense involved would not be sufficient to justify refusal to reinstate a veteran within the protection of the law.

Third Parties Not Involved

The employer's changed circumstances must make it unreasonable *as to the employer* to require restoration. The effect on third parties is immaterial, such as the effect of reemployment of veterans upon other employes. Exception is the situation where the status of a veteran reemployed may be disturbed by the reinstatement rights of other veterans having prior claim. And, since the Supreme Court decision on super-seniority, non-veterans with greater seniority rights becomes another exception.

Out of Business

Where the veteran's former employer has ceased business, such employer has no legal obligation to give the veteran employment. However, a mere change in the method of carrying on the business or a change in the name of the employer would not constitute a cessation of business.

Transfer of Ownership

The transfer of ownership, reorganization, or merger of the employer's business will not ordinarily operate to defeat the reemployment rights of returning veterans.

If, at the time the veteran makes application for reinstatement within the 90-day period, the employer's plant or business is temporarily shut-down, the employer is under legal obligations to restore the veteran when the plant reopens.

In the case of partial shut-down or lay-off, a veteran with the statutory right of one year's employment may not be laid off, subject only to the superior claims of other employes, based on seniority. It was on a situation involving this point of lay-offs that the Supreme Court ruled against the so-called super-seniority of veterans. If the shut-down or lay-off is a complete one, the veteran is subject to be laid off the same as other employes.

The veteran's right of employment continues for one year after reinstatement and may not be terminated by temporary shut-down or lay-off. Upon termination of a temporary shut-down or lay-off within the one-year period, a veteran has the same right of reinstatement that he had upon initially making application to be restored to his former position or a position of like seniority, status and pay.

The one-year period during which a veteran may not be discharged without cause is not extended by temporary shut-downs or lay-offs and ends one year from the date of the initial reinstatement.

THE MONTH IN THE INDUSTRY

API Division of Refining General Committee Named

William R. Boyd, Jr., president of the American Petroleum Institute, announced the following membership of the General Committee of the institute's Division of Refining, following the annual meeting at Chicago in November:

Hines H. Baker, Humble Oil and Refining Company, Houston; Reid Brazell, Leonard Refineries, Inc., Alma, Michigan; W. F. Burt, Socony-Vacuum Oil Company, New York; H. S. Chase, Tide Water Associated Oil Company, New York; G. A. Davidson, Standard Oil Company of California, San Francisco; C. E. Davis, Shell Oil Company, New York; David E. Day, Richfield Oil Corporation, Los Angeles.

Sylvester Dayson, Premier Refining Company, Longview, Texas; P. N. Fortin, Yale Refining Company, Billings, Montana; A. P. Frame, Petroleum Advisers, Inc., New York; M. Halpern, The Texas Company, New York; D. P. Hamilton, Root Petroleum Company, Shreveport; C. L. Henderson, Vickers Petroleum Company, Wichita, Kansas; E. J. Henry, The Atlantic Refining Company, Philadelphia; H. Y. Hyde, Tide Water Associated Oil Company, San Francisco.

C. A. Johnson, Socal Oil & Refining Company, Los Angeles; F. B. Koontz, Mid-Continent Petroleum Corporation, Tulsa; Harry A. Logan, United Refining Company, Warren, Pennsylvania; R. E. Luton, The Ohio Oil Company, Robinson, Illinois; W. C. MacDuffie, Wilmington Gasoline Company, Los Angeles; J. Howard Marshall, Ashland Oil & Refining Company, Ashland Kentucky.

E. B. McConnell, The Standard Oil Company (Ohio), Cleveland; W. E. Moody, Deep Rock Oil Corporation, Cushing, Oklahoma; H. D. Moyle, Wasatch Refining Company, Salt Lake City; W. R. Newman, 3 Frontier Refining Company, Cheyenne.

J. W. Newton, Magnolia Petroleum Company, Beaumont; Glenn E. Nielson, Husky Refining Company, Cody, Wyoming; H. G. Osborn, Continental Oil Company, Ponca City; G. G. Oberfell, Phillips Petroleum Company, Bartlesville; M. G. Paulus, Standard Oil Company (Indiana), Chicago.

Arthur E. Pew, Jr., Sun Oil Company, Philadelphia; Roland Rodman, Bay Petroleum Company, Denver; J. B. Rogerson, Lion Oil Company, El Dorado, Arkansas; G. L. Rowsey, Taylor Refining Company, Taylor, Texas; M. R. Ryan, Talco Oil & Refining Company, Mt. Pleasant, Texas.

W. F. Sims, Panhandle Refining Company, Wichita Falls, Texas; W. A. Slater, Gulf Oil Corporation, Pittsburgh; C. F. Smith, Standard Oil Company (New Jersey), New York; R. G. Sonneborn, L. Sonneborn & Sons, New York; W. L. Stewart, Jr., Union Oil Company of California, Los Angeles; Wm. A. Stoll, Stoll Oil Refining Company, Louisville, Kentucky.

G. H. Taber, Jr., Sinclair Oil Corporation, New York; James W. Vaiden, Skelly Oil Company, Tulsa; C. B. Watson, The Pure Oil Company, Chicago; W. S. Zehrung, The Pennzoil Company, Oil City.

R. B. Anderson, Waggoner Estate, Vernon, Texas; C. M. Boggs, Kanotex Refining Company, Arkansas City, Kansas; Walter S. Hallanan, Plymouth Oil Company, Pittsburgh; I. A. O'Shaughnessy, The Globe Oil & Refining Company, St. Paul, Minnesota, and Earl W. Webb, Ethyl Corporation, New York.

The last five named are directors of the institute.

William T. Gunn is director of the division.

WPRA Annual Convention To Be in San Antonio

The annual meeting of Western Petroleum Refiners' Association for 1947 will be held March 24, 25 and 26 in San Antonio. The Plaza Hotel has been selected as headquarters.

The announcement followed a meeting of directors at headquarters in Tulsa and read in part:

"We suggest that you make reservations for the accommodations necessary for those attending.

"Plans for an interesting and instructive program are going forward and preliminary announcements will be made at an early date."

In addition to the headquarters hotel, accommodations are available in the St. Anthony and Gunter Hotels.

Shell Chemical to Make Synthetic Glycerin

Shell Chemical Company has announced addition of a synthetic glycerin unit to its combination of petro-chemical units, which are adjacent to the refining plant of Shell Oil Company at Deer Park, Houston suburb. Facilities for making this product will cost $7,000,000, bringing expenditures for the whole combination of chemical processing of the company to $32,000,000 for this installation. In addition the oil company recently completed a $15,000,000 Fluid catalytic unit with necessary accessory equipment and has announced addition of a $10,000,000 lubricating oil unit for the Houston area.

Announcement of the new glycerin unit contained this information:

"Synthetic manufacture of glycerin by a process developed in the laboratories of Shell Company at Emeryville, California, will add to the supply now being produced by the soap manufacturers.

"In the new Shell plant glycerin will be manufactured synthetically from a stable supply of propylene, chlorine and caustic soda.

"Shell scientists, having conducted pilot plant production of synthetic glycerin over a long period, state that it meets all requirements as a high quality chemically pure product. Manufacturers using glycerin in their processes find that it passes the rigid specifications imposed on their products."

Conventions

March

20-22—American Institute of Mining and Metallurgical Engineers, annual meeting, Waldorf-Astoria Hotel, New York.

April

7-9—National Association of Corrosion Engineers, annual meeting, Palmer House, Chicago.

23-25—Natural Gasoline Association of America, annual meeting, Baker Hotel, Dallas.

30—American Gas Association, spring meeting, Stevens Hotel, Chicago (through May 2).

May

6-8—Petroleum Industry Electrical Association and Petroleum Electrical Supply Association, Rice Hotel, Houston.

Big-Inch Line Disposal Again Before Congress

Chaos overcame chaos temporarily when John L. Lewis' strike induced Washington authorities to make a four-month lease of the Big-Inch pipe lines for transmission of gas from the Southwest to Ohio. Loosening of this Gordian knot is temporary, and satisfies none of the conflicting interests who tied the knot, but it does serve to put disposal of the government's investment in the emergency-built lines back into the hands of Congress. Possibly a new start in a new Congress will permit equalization of political pressure for and against use of the lines for oil or for gas, and such equalization to result in acceptance of the offer with the best cash return to the taxpayer.

How confused is the issue is only partially revealed by this report of the closing hearings before the House surplus property committee, at which way was paved for consideration of a new policy in disposing of the lines by the incoming Congress.

That such a policy would be reported was disclosed by War Assets Administrator Robert M. Littlejohn in the closing hours of the hearings.

As the committee concluded its investigation, it had as its accomplishments the blocking of sale of the lines to Big Inch Oil, Inc., finally admitted by Littlejohn to be the lowest of the four bidders making the highest cash offers, and the putting of the lines to work to carry gas to the Appalachian area during the coal-strike emergency.

Ralph K. Davies, acting director of the Oil and Gas Division, reported that gas went into the line December 5, less than 72 hours after Tennessee Gas and Transmission Company was given a four-month lease.

Interior Secretary J. A. Krug, subpoenaed, told of the TGT agreement to carry natural gas to Ohio destinations. Krug said the gas would release coal for use in the East, that within a week 50 million cubic feet a day would be moving through the lines and the supply will reach 150 million cubic feet within four or five weeks.

Incidentally, the government will get about $1,000,000 out of the deal, some 75 percent of it from the 6 cents per

thousand feet which TGT will pay and the rest from the saving of maintenance work which the company is to assume.

Krug disclosed that he "took the measure of the lines" during the coal strike last spring with a view to using them if the strike was not settled. Upon receipt of John L. Lewis' letter October 21 which indicated to him that another strike was imminent, he said, he inquired of Littlejohn if disposition of the Big Inch system couldn't be held up until the situation clarified.

At that time, Krug testified, Littlejohn was certain he would have accepted one of the 16 bids then before him, but later advised that he would hold the deal up until November 15. Committee hearings opened four days later, at which time Littlejohn announced rejection of all proposals. Krug said he had not suggested rejection of the bids.

John Bauer, spokesman for a group which bid on the lines, told the committee that the government should have adopted a policy of operating the lines in the public interest, but since it did not his group, for which Thurman Arnold, former head of the Justice Department anti-trust division, and Abe Fortas, former Undersecretary of the Interior, are counsel, proposed to perform such service which, he declared, was the only way in which Eastern consumers could get cheaper supplies.

Refiners of the Middle West would suffer severely if the lines are retained in oil service, it was asserted by John Porter, president of the Texas Independent Producers and Royalty Owners Association, who said the coal states are unnecessarily alarmed about the encroachment of natural gas.

Admiral F. J. Horne, chairman of the Army-Navy Petroleum Board, challenged Littlejohn's statement that rejection of bids was due to a change in the position of the board respecting the use of the lines. The board, Horne said, believes that the lines should be disposed of to industry for use; no recommendation is made as to what industry should get them; if disposed of for any purpose other than petroleum, provision should be made for reconversion in the event of an emergency, and the expediency of reconversion in time of emergency should be determined on the basis of conditions then existing.

Former Surplus Property Administrator W. Stuart Symington, now Assistant Secretary of War for Air, whose "blue book" report of last January 4 was considered by Littlejohn a mandate to restrict the use of the lines to oil, denied that it foreclosed disposition of the system for gas or any other use. He said the blue book offered "no hindrance whatever" to sale or lease for any purpose, although he admitted it favored use for oil and specified only in the event such use was not possible should the lines be converted.

Harold L. Ickes told the committee that they could solve the problem of waste gas in West Texas. He paid his respect to everybody connected with the lines, even remotely, but bore down heavily on the bid of Big Inch Oil, Inc. Serious charges were leveled against Reconversion Director John R. Steelman, "confidant of President Truman and long-time friend of John L. Lewis," who, he suggested, should be asked "whether, a short time ago, he called the administrator of WAA by telephone to suggest that if the inadequate bid for these pipe lines for the alleged transportation of oil were accepted, it would be helpful in settling the coal strike."

The TGT lease, he pointed out, may be extended a number of times, and it will have the effect of throwing the whole matter into Congress "where pressures from coal operators, coal miners and railroads, to say nothing of oil companies, may prove to be sufficient to make these pipe lines unavailable as permanent gas carriers."

Ickes suggested that the Attorney General scrutinize the lease from the standpoint of turning over to the company "the only line in the country that had possibilities as a competitor. Ickes said the company was tied up with a number of other companies, including Columbia Gas and Electric which, together with the Hope Pipe Line Company, was set up by Standard Oil Company (New Jersey).

Speaking of Krug's testimony that the lease had been made, Ickes said: "In my opinion, there was unfolded before this committee yesterday as choice a bit of slick politics as the country has been privileged to see for a long time."

Eugene Holman, president of Standard Oil Company (New Jersey), sent Ickes a quick telegram denying the company had any interest in TGT or any intention of acquiring an interest in the pipe lines. Charles H. Smith, president of Big Inch Oil, Inc., sent him a letter, denying that his bid for the lines was predicated on any "promotional" scheme.

Gardiner Symonds, TGT president, denied that his company was affiliated with any of the companies mentioned by Ickes, beyond the fact that some of them are customers.

Symonds disclosed that he first learned his company had been given an interim contract when Krug so testified. He was not unduly concerned about Ickes' suggestion that it violated the anti-trust laws, he explained, because all of the company's operations are under government control.

Expressing the opinion that the contract would not affect the permanent disposition of the lines, Symonds said that all estimates set a year as the minimum time in which they could be readied for gas service and, in view of the current and prospective materials outlook, it would be nearer two years. His company considered bidding for the lines, he added, but decided it should not seek new markets until it could adequately meet the demands of its present customers.

Steelman declined to appear before the committee, but in a letter denied that he had ever intervened in any manner in the problems involved in the disposition of the lines. He had one conversation with Littlejohn, during which he asked the administrator whether it would be possible to use the lines for gas, Steelman said, and Littlejohn explained he felt bound to follow the oil-preference recommendation of the Symington report.

Legality of any sale of the pipe lines for gas was questioned by James W. Haley, attorney for the National Coal Association, who based his argument on provisions of the Surplus Property Act which prohibit the sale or lease of facilities in such a way as to disrupt the economy. The lines should be maintained in stand-by, he contended.

Apparently as an afterthought, Haley said the coal industry probably would not fight conversion of the lines if they were required to make up 75 percent of their load from flare gas.

The Interior Department's views, as presented by OGD's Acting Director Davies, call for sale for private operation, in gas service, on terms protecting the national safety and promoting the conservation of gas, just as quickly as possible.

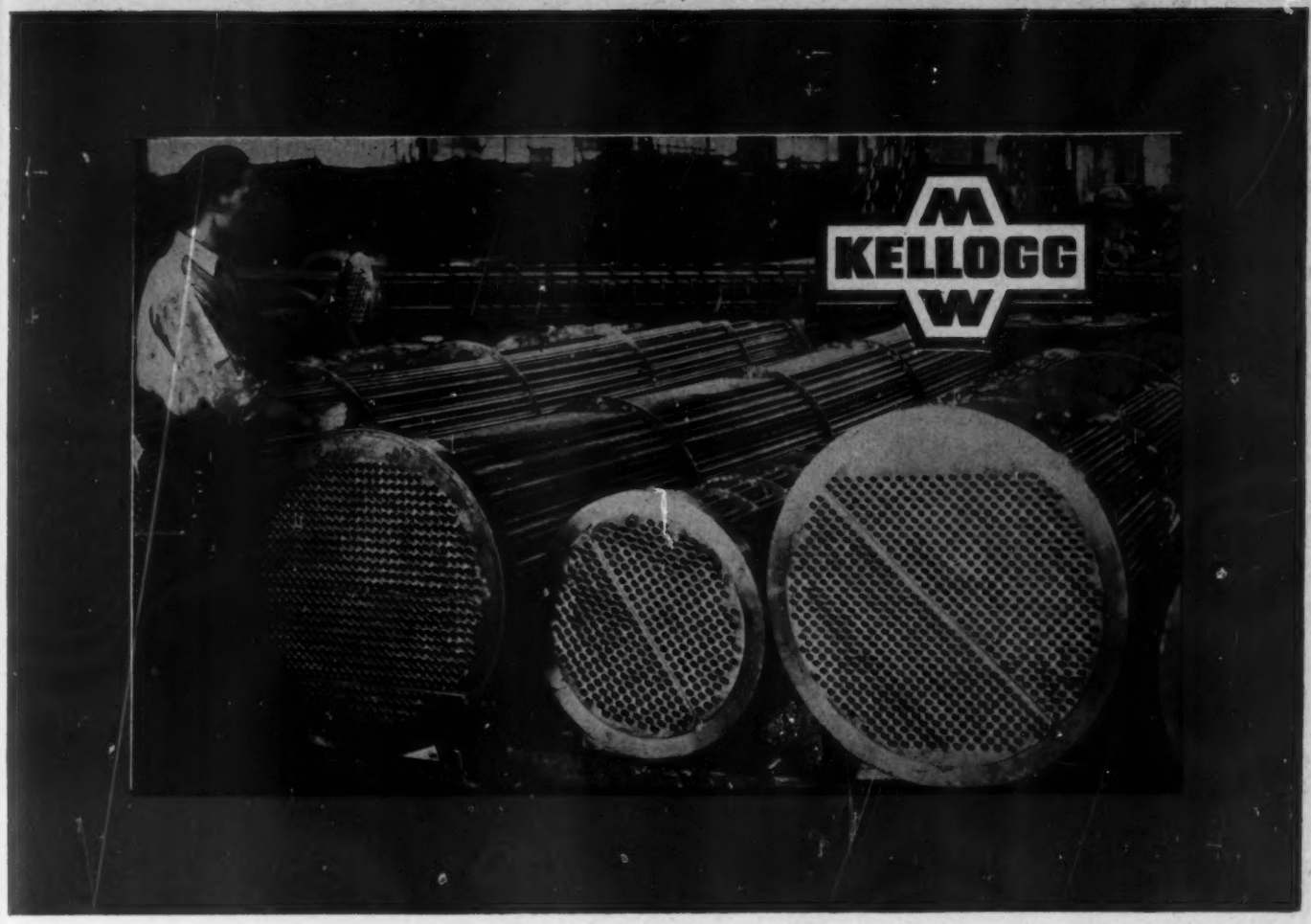
Davies warned that the government must neither retain ownership of the lines nor attempt to operate them. If the lines were kept by the government, he said, then with equal justification "every line with which they might compete and every line with which such competing lines might compete should also be owned by the government, which would mean that the entire pipe line system east of the Rocky Mountains would be government-owned." Such an absorption, he added, would be "abhorrent,"

Trends of Operations and Changes in Stocks

Figures on crude stocks are from Bureau of Mines weekly reports; all others from American Petroleum Institute weekly reports, which are estimates on Bureau of Mines basis.

(All figures in thousands of barrels—add 000)

Trends in Week Ended	Crude Oil			Gasoline		Gasoil nd Distillate		Residual Fuel	
	Production Daily	Runs to Stills Daily	Stocks Week End	Production Weekly	Stocks Week End	Production Weekly	Stocks Week End	Production Weekly	Stocks Week End
1945:									
January 27	4,727	4,756	221,310	14,957	88,223	4,843	33,561	9,252	51,119
February 24	4,777	4,803	219,351	15,500	95,972	4,958	28,753	9,084	46,713
March 31	4,781	4,677	223,782	14,644	98,758	4,548	26,889	9,184	41,745
April 28	4,805	4,780	223,474	14,633	94,068	4,636	28,273	9,379	39,813
May 26	4,887	4,950	222,831	15,194	89,121	4,667	29,184	9,670	38,548
June 30	4,903	4,999	220,781	15,546	86,472	4,910	32,213	9,077	40,488
July 28	4,930	4,996	218,507	16,106	86,008	4,598	36,071	9,586	42,283
August 25	4,892	4,931	e211,813	15,986	84,693	4,960	39,782	9,356	46,201
September 29	4,357	3,812	222,387	11,913	79,552	3,940	43,689	7,047	46,853
October 27	4,273	4,838	224,230	15,530	74,335	5,159	43,472	8,691	45,943
November 24	4,469	4,648	219,363	15,681	83,184	4,802	45,258	8,800	47,474
December 29	4,474	4,729	218,918	14,546	95,205	5,055	36,651	8,765	42,447
1946:									
January 26	4,626	4,553	220,544	13,622	101,737	5,720	29,498	8,411	39,722
March 2	4,726	4,779	229,430	13,871	104,462	5,888	25,148	8,634	38,441
March 30	4,425	4,684	224,994	13,996	104,715	5,337	28,240	8,738	37,746
April 27	4,672	4,685	224,443	14,228	99,631	5,568	30,466	9,204	39,404
May 25	4,759	4,857	222,214	14,322	95,769	5,463	32,973	8,908	43,368
June 29	4,957	4,854	223,883	14,500	92,333	5,325	37,762	8,828	46,447
July 27	4,926	4,896	223,756	14,535	88,236	5,817	44,316	8,217	49,517
August 24	4,836	4,866	225,672	14,639	86,251	5,649	51,405	8,126	52,061
September 28	4,778	4,829	221,903	14,538	85,854	5,450	57,903	8,158	56,914
October 26	4,730	4,758	221,184	14,863	86,423	5,710	65,499	7,728	60,872
November 30	4,795	4,707	225,119	15,145	88,371	5,228	66,062	7,672	58,647



KELLOGG HEAT TRANSFER EQUIPMENT

To Meet Specific Operating Conditions

Kellogg heat exchangers and heat transfer equipment of specialized design have been installed in many refineries producing vital war materials.

Their selection was due to the fact that Kellogg engineers, specialists in heat transfer problems, had designed and installed hundreds of thousands of square feet of heat transfer surfaces in leading refineries of the United States and foreign countries. Correct design, rugged construction, flawless materials, and the most accurate workmanship were combined to produce heat exchangers which operated efficiently and economically.

Kellogg offers to refiners the experience of outstanding specialists in heat transfer problems in collaboration with the Kellogg chemical and physical laboratories to aid in solving refinery heat transfer problems.

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but government operation would be even more repugnant.

From the national standpoint, Davies continued, no one now can say that the Big Inch lines will be needed in the next emergency.

"The way to insure the availability of the Big Inch lines for overland carriage of oil above peacetime pipe-line capacity is to keep them out of peacetime use as oil carriers," he declared.

Davies stressed the need and increasing demand for natural gas, which can be distributed only through pipe lines; the abundance of the fuel in the Southwest, and the gas now being wasted which could be moved through the Big Inch system.

The plan to ask the bidders informally to make new offers which he suggested November 19 has been dropped, and meetings have been arranged with other interested agencies at which an agreement will be sought which will permit WAA to submit a supplemental report to Congress, ask for new bids placing all bidders on an equitable basis, and dispose of the lines at an early date for maximum cash.

Murray to Succeed Jester On Texas Commission

William J. Murray, Jr., of Houston has been named a member of the Railroad Commission of Texas to succeed Beauford H. Jester when the latter becomes governor of the state on January 1.

Murray formerly was employed by the commission and at one time headed its engineering department. He received a degree in petroleum engineering from University of Texas in 1936. During the war he held various positions with PAW, and recently has been a consulting engineer.

Ethyl Holds Open House At Detroit Laboratory

Formal opening of the research laboratories of Ethyl Corporation in Ferndale, a Detroit suburb, took place November 13, 14 and 15 as an open house. These laboratories were nearing completion at the time of the attack on Pearl Harbor. Immediately construction was accelerated so the facilities could be used in research of military nature.

During the war public inspection was not permissible and the open house in November was the first opportunity of giving engineers of related industries an opportunity of general inspection, although a few had been privileged to visit the facilities during the war period.

At the time of the open house a bronze plaque in honor of Thomas Midgley, Jr., was placed in the main lobby of the building. Midgley, who died in 1944, was the discoverer of tetraethyl lead. Among his other achievements was the demonstration of removing bromine from sea water, the discovery of a new series of nontoxic and noninflammable refrigerants, as well as researches into the composition of natural and synthetic rubbers, and of the chemistry of vulcanization.

The new facilities serve in cooperative research with automobile, aircraft and petroleum industries in coordinating the development of motor fuels and engines. The equipment is designed for research on engines of passenger automobiles, trucks, busses, light aircraft, farm tractors and stationary units. Electronic equipment is used extensively in instruments and control apparatus. Specially designed automatic control devices vary the throttle opening, speed and load of engines during operation on dynamometers in simulation of any selected kind of actual service. One such unit operates on the principle of a player piano, and can automatically duplicate the continuously changing conditions imposed on an engine during an eight-hour cross-country trip. In the "hot room" and "cold room," entire vehicles can be operated with their rear wheels driving large rolls set at floor level, and with powerful blowers automatically directing a blast of air against the radiators at speeds corresponding to the speed of the rear wheels. The refrigerating coils for the cold room contain more than three miles of 1¼-inch steel pipe, and the refrigeration capacity is enough to keep the temperature in the room at zero when a large passenger car is being operated in it with wide open throttle at 60 miles per hour. The temperature in the "hot room" can be maintained as high as 150 degrees. Special single-cylinder engines are used for research on gasolines under any desired conditions, including supercharging and extremely high compression ratios which are predicted for automobile and truck engines of the future. Some of these special engines are supercharged to permit studies of aviation fuels under conditions representative of those in the most powerful of reciprocating aircraft engines. Extensive and fully equipped chemical laboratories are provided, which synthesize and evaluate the usefulness of new organic compounds and complement the work of engineers engaged in research on engines, fuels and lubricants.

The laboratories include complete auxiliary facilities, such as shops for metal working, woodworking, painting, electrical repair and general maintenance, as well as sections concerned with photography and the development of instruments and experimental apparatus. A combination cafeteria and auditorium, and both indoor and outdoor facilities for employe recreation are provided. Extensive lawns with many trees and shrubs surround the buildings, and the plant is one of the most attractive in the Detroit area. The total floor space is in excess of 123,000 square feet, and over 300 people are employed.

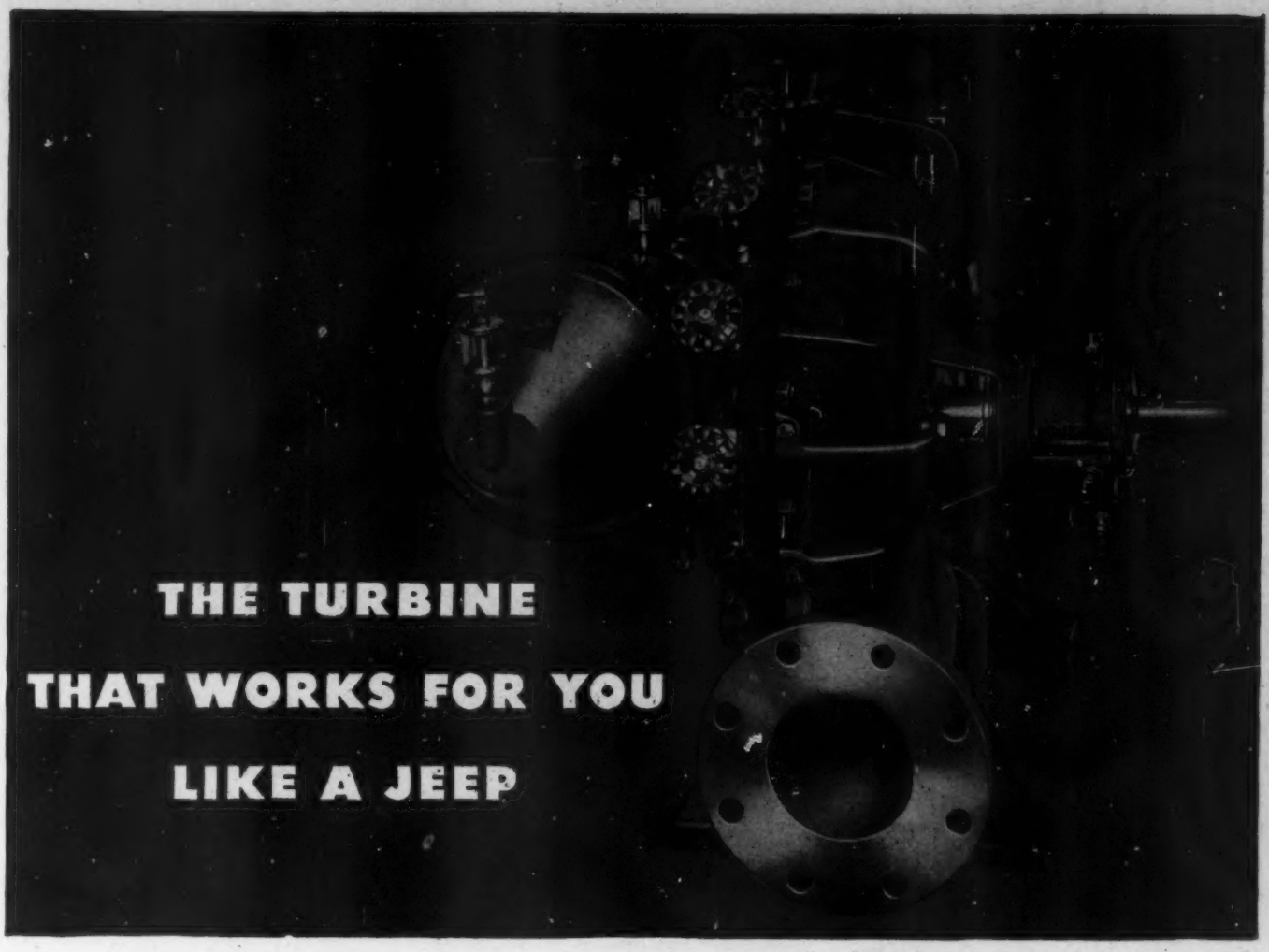
Complementing the Detroit Laboratories of Ethyl Corporation is the company's laboratory at San Bernardino, California. Facilities there include engine and chassis dynamometers, CFR-fuel-test engines, equipment for chemical inspection of gasolines, and an experimental garage with equipment for the conduct of research on vehicles on the road. Roads suitable for research work are available at elevations ranging from 200 feet below to 7000 feet above sea level. Road grades range up to 12 percent. Weather conditions vary from extreme summer heat on the desert to winter cold in the mountains. The San Bernardino Laboratory is on a 25-acre tract of land, has slightly more than 16,000 square feet of floor space, and employs 31 people.

Main entrance to Ethyl Corporation's research laboratory at Detroit, Michigan

API Committee on Public Relations Is Announced

Following approval of a program of public relations activity on behalf of the industry at its annual meeting in Chicago last month, a nationwide committee, headed by John M. Lovejoy, Seaboard Oil Company, New York, as chairman, has been named to direct the program. "The new committee," the announcement pointed out," is designed to represent the entire country not only geographically but every phase of the industry as well.

"This public relations committee of the board of directors will be a policy-



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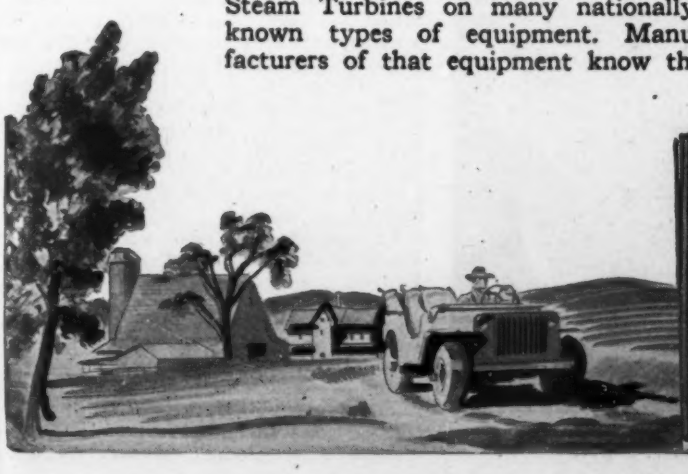
The Coppus line of "Blue Ribbon" turbines runs from 150 HP down to fractional — there are six frame sizes, and prices are in proportion. You can match a Coppus turbine to the job, saving the money you might otherwise spend for a turbine that's larger than necessary.

You'll see Coppus "Blue Ribbon" Steam Turbines on many nationally-known types of equipment. Manufacturers of that equipment know the quality that is represented by the Coppus "Blue Ribbon" — more than 85% of all orders since 1937 has been repeat business.

Select the right size of Coppus turbine for any job that calls for "jeep duty". Like all Coppus "Blue Ribbon" products (blowers, ventilators, gas burners, etc.), they are made to extremely close tolerances with accuracy controlled by Johansson size blanks. Before shipment, every turbine is dynamometer-tested.

Write for Bulletin 135–10. Coppus Engineering Corporation, 532 Park Avenue, Worcester 2, Mass. Sales offices in THOMAS' REGISTER. Other Coppus "Blue Ribbon" products in SWEET'S.



ANOTHER
COPPUS
"BLUE RIBBON" PRODUCT

THE MONTH . . .

making committee, under whose general supervision the new public-relations program will be financed, organized and conducted."

Several sub-committees are to be named by the chairman. Members of the general committee are:

R. H. Colley, The Atlantic Refining Company, Philadelphia; J. Frank Drake, Gulf Oil Corporation, Pittsburgh; Eugene Holman, Standard Oil Company (New Jersey), New York; Alexander Fraser, Shell Oil Company, New York; W. S. Hallanan, Plymouth Oil Company, Pittsburgh; B. Brewster Jennings, Socony-Vacuum Oil Company, New York; W. A. Jones, Cities Service Company, New York; H. A. Logan, United Refining Company, Warren, Pennsylvania; J. Howard Pew, Sun Oil Company, Philadelphia; W. S. S. Rodgers, The Texas Company, New York; Earle W. Webb, Ethyl Corporation; New York; Ralph T. Zook, Sloan & Zook, Bradford, Pennsylvania.

K. S. Adams, Phillips Petroleum Company, Bartlesville; T. H. Barton, Lion Oil Company, El Dorado, Arkansas; C. L. Henderson, Vickers Petroleum Company, Wichita; B. L. Majewski, Deep Rock Oil Corporation, Chicago; W. G. Skelly, Skelly Oil Company, Tulsa; W. K. Warren, Warren Petroleum Corporation, Tulsa; L. S. Wescoat, The Pure Oil Company, Chicago; R. E. Wilson, Standard Oil Company (Indiana), Chicago.

J. L. Hamon, Cox & Hamon, Dallas; B. A. Hardey, Independent Petroleum Association of America, Shreveport; Geo. A. Hill, Jr., Houston Oil Company of Texas, Houston; C. F. Roeser, Roeser and Pendleton, Inc., Fort Worth; H. C. Wiess, Humble Oil & Refining Company, Houston.

W. H. Ferguson, Continental Oil Company, Denver; Henry D. Moyle, Wasatch Oil Refining Company, Salt Lake City; Paul Stock, Yale Petroleum Company, Cody, Wyoming.

L. L. Aubert, Bankline Oil Company, Los Angeles; R. G. Follis, Standard Oil Company of California, San Francisco; W. F. Humphrey, Tide Water Associated Oil Company, San Francisco; A. C. Mattei, Honolulu Oil Corporation, San Francisco; Ralph B. Lloyd, Lloyd Corporation, Los Angeles; Reese H. Taylor, Union Oil Company of California, Los Angeles.

Whealey Superintendent At Ashland Refinery

Roland Whealey has been named general superintendent of the plant of Ashland Oil & Refining Company, Catlettsburg, Kentucky. His appointment was announced November 6 when all workers were guests of the management in celebration of a record of eight months of operation without a lost-time accident.

Whealey has been acting general superintendent since September 15, following the resignation of E. A. Brown. Previously he has been superintendent of the laboratory and the blending and testing department.

Chester F. Smith Named Standard Vice President

Chester F. Smith, a director of Standard Oil Company (New Jersey) and for more than 35 years associated with the company in manufacturing and engineering operations, was named a vice president effective December 1.

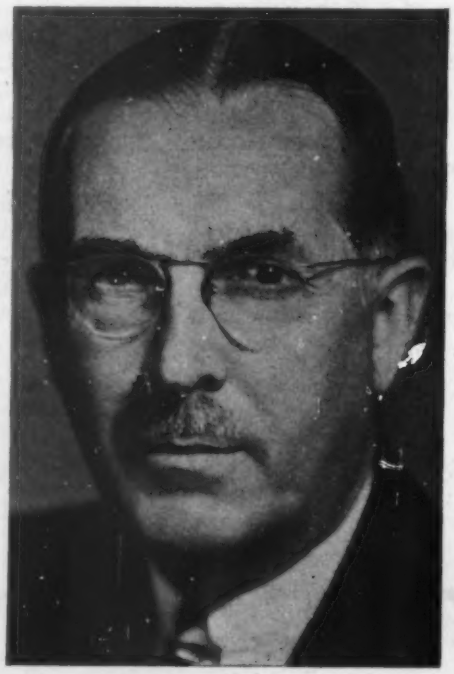
Since 1944, Smith has been chairman of the company's coordination committee, a central study and advisory group for the managements of companies in the Jersey group. Members of the committee are appointed by the board and include executives of some affiliated companies as well as department heads of the parent company.

Created some years ago as another step in decentralization of Jersey management, the committee now headed by Smith meets regularly to review such matters as quality of products, producing and refining techniques, supply-and-demand outlooks. Working with the committee as a whole in its long-range planning are subcommittees of executives and department heads who report on trends in domestic and foreign operations, and a chemical policy committee to review research and development.

The appointment of Smith increases the number of vice presidents of Standard Oil Company (New Jersey) to four. The others are Orville Harden, John R. Suman and Robert T. Haslam, all of whom are also directors of the company.

From 1940 until his appointment as a director in 1944, Smith was president of Standard Oil Company of New Jersey, the principal refining and marketing subsidiary of the parent company.

A native of Bayonne, N. J., Mr. Smith attended the city's public schools and was graduated from Pingry school at Elizabeth in 1908. He started his career with the Jersey group that year, remaining in the Bayonne laboratory until the fall of 1909 when he entered the University of Pennsylvania. He was graduated in 1913 in mechanical engineering.



CHESTER F. SMITH

Returning to the company, Smith accepted a position in the engineering department. Shortly after, he was made assistant superintendent of case and can operations at Bayonne and later became superintendent of that department. In 1922, he was appointed assistant to the general superintendent of the Bayonne refinery and four years later was made the refinery's general manager. He was appointed manager of the Bayonne plant in 1928 and in 1931 became assistant general manager of the company's three New Jersey refineries. From 1933 until 1940, he was vice president of the operating company and general manager in charge of its refineries.

Asphalt Institute Elects Oklahoma Man President

At their annual meeting in New York December 4, directors of The Asphalt Institute, representing the major part of the petroleum asphalt production industry of the United States and Canada, elected C. Wayne Barbour of Allied Materials Corporation, Oklahoma City, president and chairman of the executive committee, with George R. Christie, Socony-Vacuum Oil Company; Inghram Grayson, Lion Oil Company; Raymond Harsch, Shell Oil Company; James J. Kelly, Kerr-McGee Oil Industries, Inc., Fen-Ter Refining Division; D. N. Myers, Byerlyte Corporation, and J. S. Sawyer, Shell Oil Company, completing the committee.

The five vice-presidents elected with their respective divisional jurisdiction, were as follows: Atlantic-Gulf, J. S. Sawyer; Ohio - Great Lakes, D. N. Myers; Mid-West, Inghram Grayson; Southwest, James J. Kelly, and Pacific Coast, Raymond Harsch.

Bernard E. Gray was reelected general manager-chief engineer, and Herbert Spencer, secretary. F. V. Widger, Witco Chemical Company, was elected treasurer and John N. Smith, Socony-Vacuum Oil Company, assistant treasurer.

Barbour was one of the founders of Allied Materials Corporation in 1932, and is now its president. He is a graduate of the College of Engineering of the University of Oklahoma, Class of 1923.

Refinery Electric Power Problems Discussed

"Refiners' Viewpoint of Electric Power Usage," by W. H. Stueve of Oklahoma Gas & Electric Company, Oklahoma City, was among the papers presented before 100 members of the Petroleum Electric Power Association at the annual conference of the organization at Tulsa on December 3-4. He presented figures to show that the use of purchased power is the cheapest.

A discussion on the theory of pump and compressor installation was given by Fred Wetzel, Ingersoll-Rand Company, Tulsa. He illustrated his paper, "Use of Electric Power for Pumps and Compressors in Oil Refineries," with a number of charts.

In a paper on "Newer Electric Power Equipment for the Oil Industry," B. M. Brown, manager of the petroleum and chemical section of Westinghouse Electric Corporation, East Pittsburgh, showed that due to improvement of pumping equipment as well as electrical equipment, lower operation costs and maintenance will be attained.

"Use of Variable Capacity Pluger Pumps with Electric Motors for Pipe

Long the leader in development of inorganic fluorides and fluoborates, General Chemical Fluorine Research now enters the field of organic chemistry as it presents the *Genetrons* . . . an important series of aliphatic organic fluorine compounds.

First of the group is *Genetron 100*, a product significant not only as a new industrial chemical, but also as the parent compound for this family of commercially valuable organic fluorine derivatives.

Its physical properties point to various applications . . . as a refrigerant; intermediate in the preparation of aerosol dispersants, dielectrics, high pressure lubricants, selective solvents, and mixed olefinic halide monomers. Some of these uses are already being confirmed by manufacturers who recognize the unusual industrial potentialities of this low-boiling organic liquid.

Genetron 100 may merit your thorough investigation, too. For experimental samples write General Chemical Company, Fluorine Division, 40 Rector Street, New York 6, N. Y.

genetron* 100

PHYSICAL PROPERTIES

Formula	CH_3CHF_2
Molecular Weight	66.05
Color	Colorless
Melting Point	—117.0° C
Boiling Point	—24.7° C
Density	1.004 at —25° C
Latent heat of vaporization	137 B.t.u./lb.

vapor pressure (p.s.i. abs)

—30° C	12.0
—10° C	25.9
10° C	53.8
30° C	108.0

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THE MONTH . . .

Lines" was given by B. F. Thompson, Public Service Company, Tulsa. He discussed a practical variable stroke reciprocating pump manufactured by a prominent firm, and how the equipment has been aiding men in the pipe line industry.

A. N. Horne, vice president and assistant manager of the Texas - Empire Pipe Line Company, Bartlesville, in his paper on "Future Use of Electric Power for Pipe Line Pumping," said that in order to have more economy in operation of pipe line systems, operators should look to: larger diameter lines; fewer pump stations, and simplified pumping equipment. To attain the fullest economy in application of these three factors, the cost of fuel or power for the prime movers must be comparable.

Max H. Halderson, Phillips Petroleum Company, Bartlesville, discussed "What Utilities Should Do to Secure Production Business."

Paul Griffith of the Arkansas Power & Light Company, Little Rock, was named president for 1947-48, replacing H. C. LeVois, Gulf States Utilities Company, Port Arthur, Texas.

Directors named include: T. E. Graham, Oklahoma Gas & Electric Company, Oklahoma City; Watson, Landon, LeVois and McNeese; P. M. Cordell, Texas Electric Service Company, Fort Worth; J. E. Moody, Southwestern Gas & Electric Company, Shreveport; O. W. Jones, Central Power & Light Company, Corpus Christi, Texas; and R. E. Frey, Kansas Gas & Electric Company, Wichita, Kansas.

The 1947 convention will be be held in Corpus Christi.

British American Refinery Sets Safety Record

A new record for safety in the Canadian oil industry has just been set by the employes of the Clarkson, Ontario, refinery of British American Oil Company. On the third anniversary of the opening of the refinery employes established an all-time high in Canada for safety, of a million man hours without a lost-time accident. A certificate of merit was awarded to the refinery by the Industrial Accident Prevention Association at a ceremony attended by the officers of the company. W. K. Whiteford, president, lauding the feat of safety achievement in his address to the employes stated that, "our producing company in the United States at Oklahoma City this past week presented us with their record of safety of one year without a lost-time accident, heading our American operations, and now we in Canada have been able to top their record."

In recognition of their efforts and cooperation in establishing this record W. C. Gault, manager of the refinery, announced that each employe would receive an extra day's pay.

The method of tabulating as used by British American Oil Company is the Standard Industrial Accident Reporting System as approved by the National Safety Council; the American Standards Association and the Society of Safety Engineers. In June 1944 the company instituted a safety campaign at the newly built refinery at Clarkson and a full-time safety supervisor was appointed. The frequency rate for 1944 was 37.6 as compared with 14.4 for 1945, while the frequency rate for the Canadian oil industry for that year was 14.43. In 1946 one million man-hours without a lost-time accident was achieved, setting an all-time high for the oil refining industry. An intensified program of accident prevention was carried on and departmental safety committees were set up to cover topping and cracking, lube oil and maintenance. Similar safety campaigns are being conducted in the four other refineries of the company across Canada.

Mekler Opens Chicago Office as Thermal Consultant

L. A. Mekler, who has been engineering consultant of the Armour Research Foundation, has opened an office at 176 West Adams Street, Chicago, where he will specialize in thermal problems and fuel economics, especially as they affect petroleum refining and the chemical industries. He also will give attention to the evaluation of petroleum processes and plants.

Previous to joining the Armour staff as full time consultant in April, 1945, Mekler was on the staff of Universal Oil Products Company, Chicago, as a combustion engineer and a member of its engineering and development department.

Mekler is a native of Russia, and his early education was in the Junior College, Harbin, Manchuria. Later he gained a B.A. degree in metallurgy at the University of Glasgow. His formal education was completed at the University of California with a B.S. degree in 1919, although his studies were completed in 1917.

After two years with a consulting engineering firm in California, he joined Universal Oil Products Company in 1919 and remained on its staff until 1921. Then followed six years as a consulting engineer. He returned to the UOP staff in 1927 and remained until 1945. During the war period he was on the staff of the Petroleum Administration for War in charge of Russian refining requirements.

L. A. MEKLER

Shreveport Draws January WPRA Technical Meeting

The January meeting of the technical group of Western Petroleum Refiners' Association in Shreveport will consist of a question-and-answer program. The session will be held the afternoon of January 17 in the Washington-Youree Hotel. A. W. Trusty, chief chemist of Arkansas Fuel Oil Company, Shreveport, will serve as chairman. He has conducted several of the previous sessions of the question-and-answer type.

Concerning this type of program the announcement from association headquarters in Tulsa read: "Those participating have an opportunity to exchange operating experiences on any questions relating to refining operations. In order that you may come to the meeting informed as to the nature of the questions and better prepared to participate in the discussion, a list of questions submitted will be sent to you at a later date, prior to the meeting. In the meantime, you are requested to send in your questions. There is no limit to the number each person may submit. Questions should be mailed to Paul D. Williams, Technologist, Western Petroleum Refiners' Association, 1414 Hunt Building, Tulsa 3, Oklahoma."

Southwest Gas Measurement Short Course May 6-8

Representatives of the natural gas industry from 12 states attended a general committee meeting of the Southwestern Gas Measurement Short Course in Houston, Texas, November 11.

R. M. Scofield of Lone Star Gas Company, Dallas, general chairman, presided. May 6, 7, and 8 were set for holding the 1947 school to be held at the University of Oklahoma, Norman.

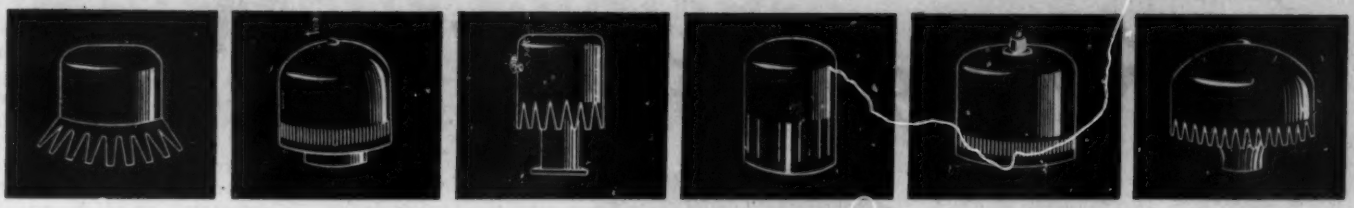
Other business of the meeting included election of committee chairmen and action on recommendations of the executive commitee. Committee chairmen elected were as follows: Program, E. C. McAninch, Oklahoma Natural Gas Company, Ardmore; Publications, W. H. Woods, Gulf Oil Corporation, Houston; Exhibits, George E. Greiner, Phillips Petroleum Company, Bartlesville; Practical Methods, B. F. Worley, United Gas Corporation, Houston, and J. L. Griffin, Northern Natural Gas Company, Omaha, Nebraska; Registration and Publicity, Miss Kate A. Niblack, Oklahoma Utilities Association, Oklahoma City; and Local Arrangements, W. H. Carson, University of Oklahoma, Norman.

The next meeting of the general committee is to be held in Oklahoma City, January 13, 1947.

Privately-Owned Pipe Lines Under ICC Authority

Interstate Commerce Commission authority extends to privately-owned pipe lines it has been ruled by the United States Supreme Court in a five-four decision. The suit involved Champlin Refining Company's 516-mile gasoline line from Oklahoma to Iowa. The company had refused information on valuation demanded by ICC, the company contending it is not engaged as a common carrier.

The opinion held that while the company challenged the ICC's jurisdiction on the ground that it transported only



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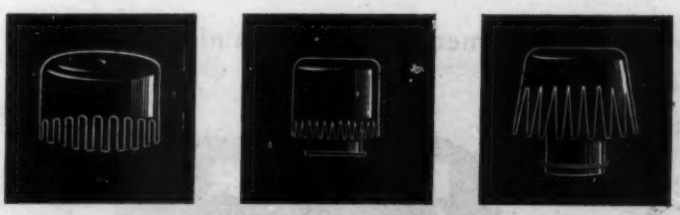
In addition to their low upkeep, they cost less to buy. Then, when designing new tower construction, sectional trays can be made lighter than required for cast iron caps.

P. S. facilities can be readily adapted for the rapid production of your style bubble cap made from any alloy steel. Send blueprint and specifications for our estimates.



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THE MONTH...

its own products, the oil actually "is not being moved for Champlin's own use."

"The power of Congress to regulate interstate commerce is not dependent on the technical common carrier status but is quite as extensive over a private carrier," he said.

Six products pipe line systems appear affected by the Champlin decision and as a result will have to file valuation reports with the ICC.

Synthetic Experts Among Scientists from Germany

Leaders in the field of development of synthetic petroleum in Germany are among the 270 German technical experts who have been brought to this country by the War Department, and more will come in under plans to increase the number to approximately 1000.

Synthetic petroleum production is being studied intensively by German scientists with experience and ability in the hydrogenation of coal, the carbonization of coal and oil shale, and the synthesis of gas by the Fischer-Tropsch process. Another group of technicians is designing a high-speed, lightweight diesel engine with low fuel consumption for marine, railroad and other uses.

The German scientists are here in War Department custody under contracts which give the best paid a top salary of $3120, plus a $6 daily expense allowance. Many of these Germans will become eligible for immigration visas. Shortly some can be released to private industry, research laboratories and educational institutions.

New Russian Process

The Soviet petroleum industry, in cooperation with research institutions, has developed a new domestic catalytic cracking process to obtain high-octane gasoline, according to Russian press reports reaching the Department of Commerce. The tests are being made at a pilot plant in the city of Grozny.

High-octane gasoline was produced from naphthyl and paraffin in the experimental distillations, and the reports state that the results of these experiments will serve as the basis for a more widespread use of the catalytic cracking process.

Vapor Pressure Chart

Phillips Petroleum Company has prepared a large scale vapor pressure chart, entitled "Vapor Pressures of Twelve Four-Carbon-Atom Hydrocarbons." The hydrocarbons included are isobutane, isobutylene, 1-butene, 1,3-butadiene, n-butane, trans-2-butene, cis-2-butene, vinylacetylene, ethylacetylene, diacetylene, 1,2-butadiene and dimethylacetylene. Vapor pressures from 0.30 to 800 psia are shown over a temperature range of —110 to +320 F.

The chart, measuring approximately 8 x 24 inches is suitable for mounting on a wall or folded for inserting in a notebook. Single copies are available free of charge upon request on your business letterhead to Phillips Petroleum Company, Chemical Products Department, Bartlesville, Oklahoma.

AUTOMATIC CONTROL EQUIPMENT

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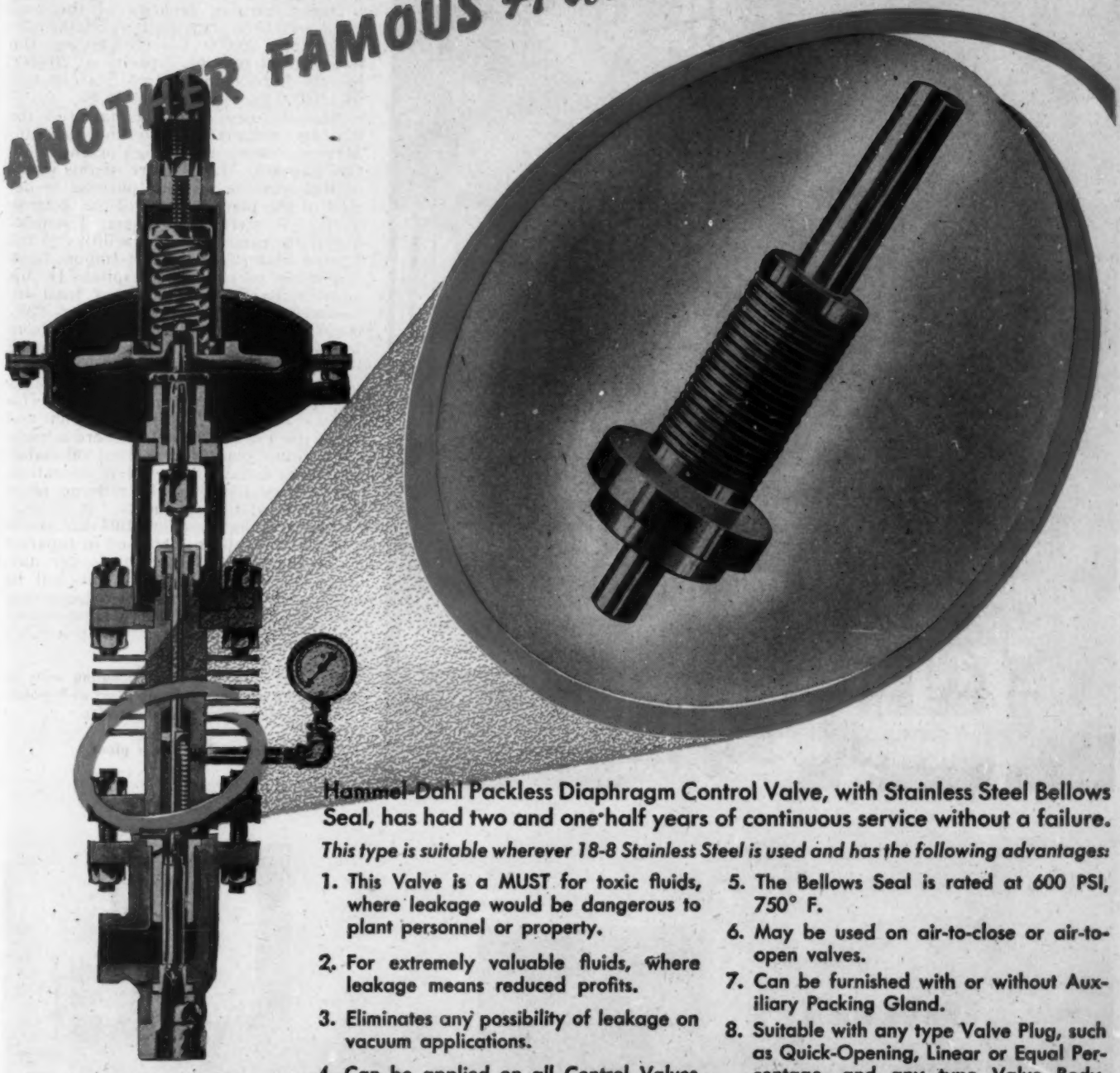

Hammel-Dahl Packless Diaphragm Control Valve, with Stainless Steel Bellows Seal, has had two and one-half years of continuous service without a failure.

This type is suitable wherever 18-8 Stainless Steel is used and has the following advantages:

1. This Valve is a MUST for toxic fluids, where leakage would be dangerous to plant personnel or property.
2. For extremely valuable fluids, where leakage means reduced profits.
3. Eliminates any possibility of leakage on vacuum applications.
4. Can be applied on all Control Valves from smallest to largest sizes.
5. The Bellows Seal is rated at 600 PSI, 750° F.
6. May be used on air-to-close or air-to-open valves.
7. Can be furnished with or without Auxiliary Packing Gland.
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Mexican Refining Capacity Expanded and Modernized

Inauguration ceremonies November 20 marked completion of expansion plans for the new refining plant of Petroleos Mexicanos at Atzapotzalco, suburb of Mexico City. At that time Efrain Buenrostro, general manager of Penmex, gave detailed information concerning expansion of the whole petroleum industry in Mexico.

Daily charging capacity of the new plant has been increased to 58,000 barrels from 23,000 barrels, giving the nation total refining capacity of 200,000 barrels daily, compared with a capacity of 120,000 barrels daily in 1938.

Also the new plant has facilities for making products formerly imported into Mexico, among them high-octane aviation gasoline. Manufacture of this grade of fuel was the primary purpose in design of the plant as part of the defense of the Western hemisphere. Financial assistance came through facilities of the United States, the Export-Import bank providing part of the capital. In his address Buenrostro said that total investment of the refining plant was $25,000,000, of which $10,000,000 came from foreign sources and that 20 percent of this has been repaid.

The whole petroleum project in Mexico included expansion of pipe-line facilities from the Tampico district and from the Poza Rica field, where a natural-gasoline plant and a crude-oil-stabilization unit have been put in operation.

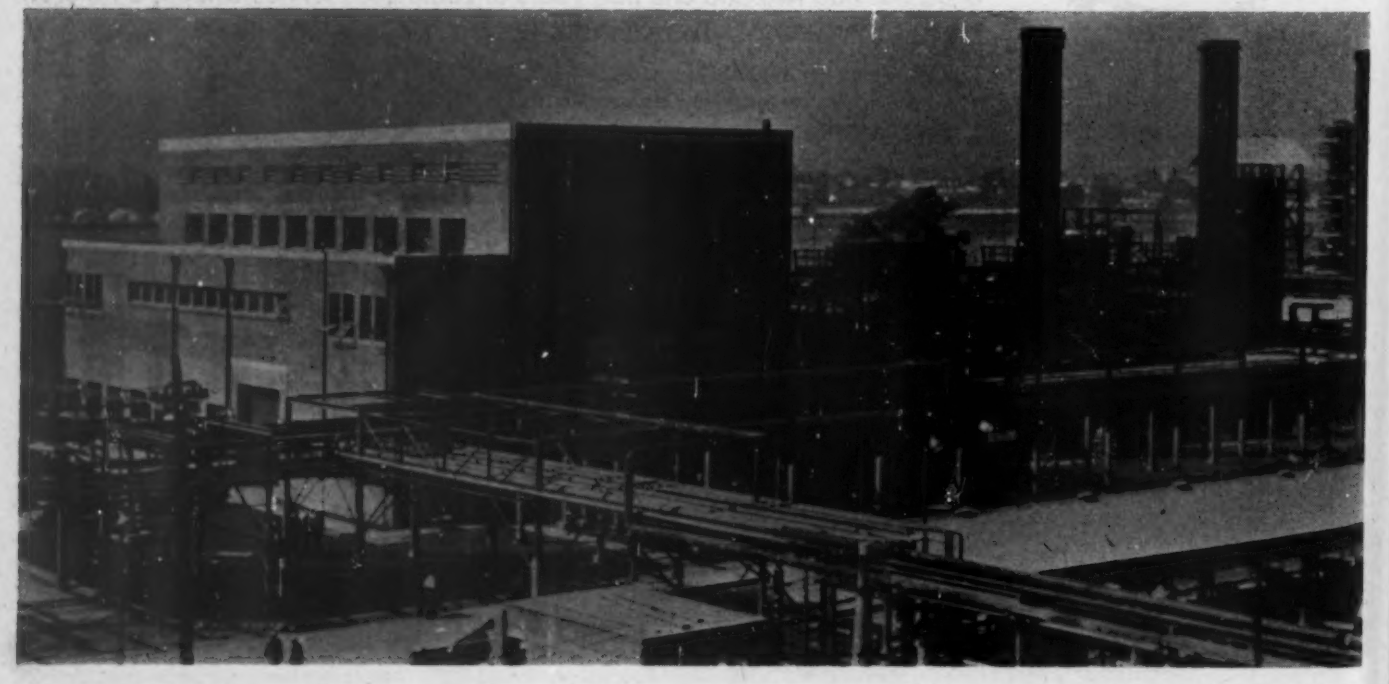
Facilities added to the refining plant near Mexico City include:

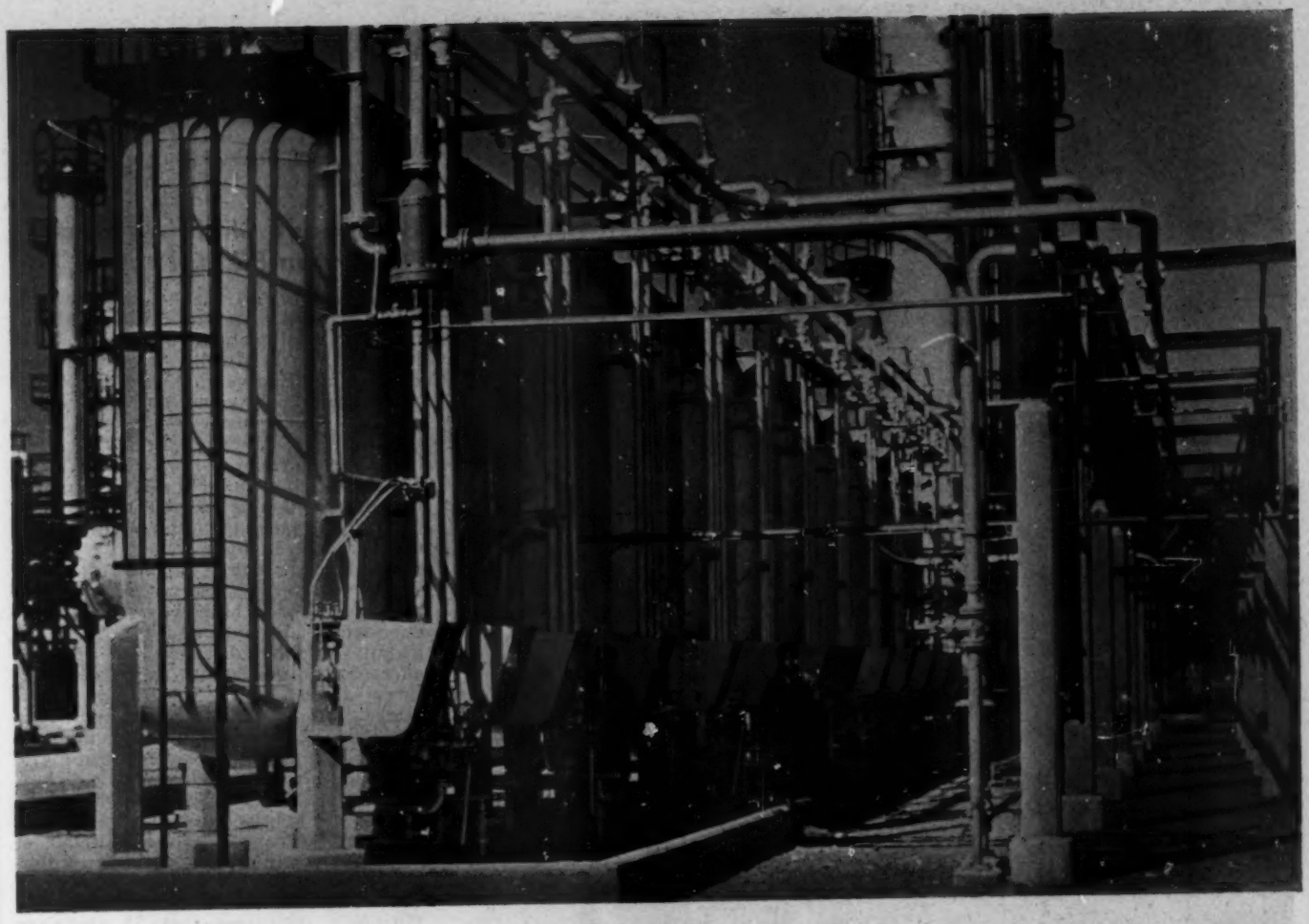
The existing topping stills at Atzcapotzalco have been increased in capacity from 18,000 to 22,000 barrels per day. Topped crude from this plant will be processed in the new thermal-cracking unit. The new plant at Atzcapotzalco consists of a topping unit with a rated

Left: Flash column and fractionating units on the topping unit, new refining plant of Petroleos Mexicanos at Atzapotzalco.

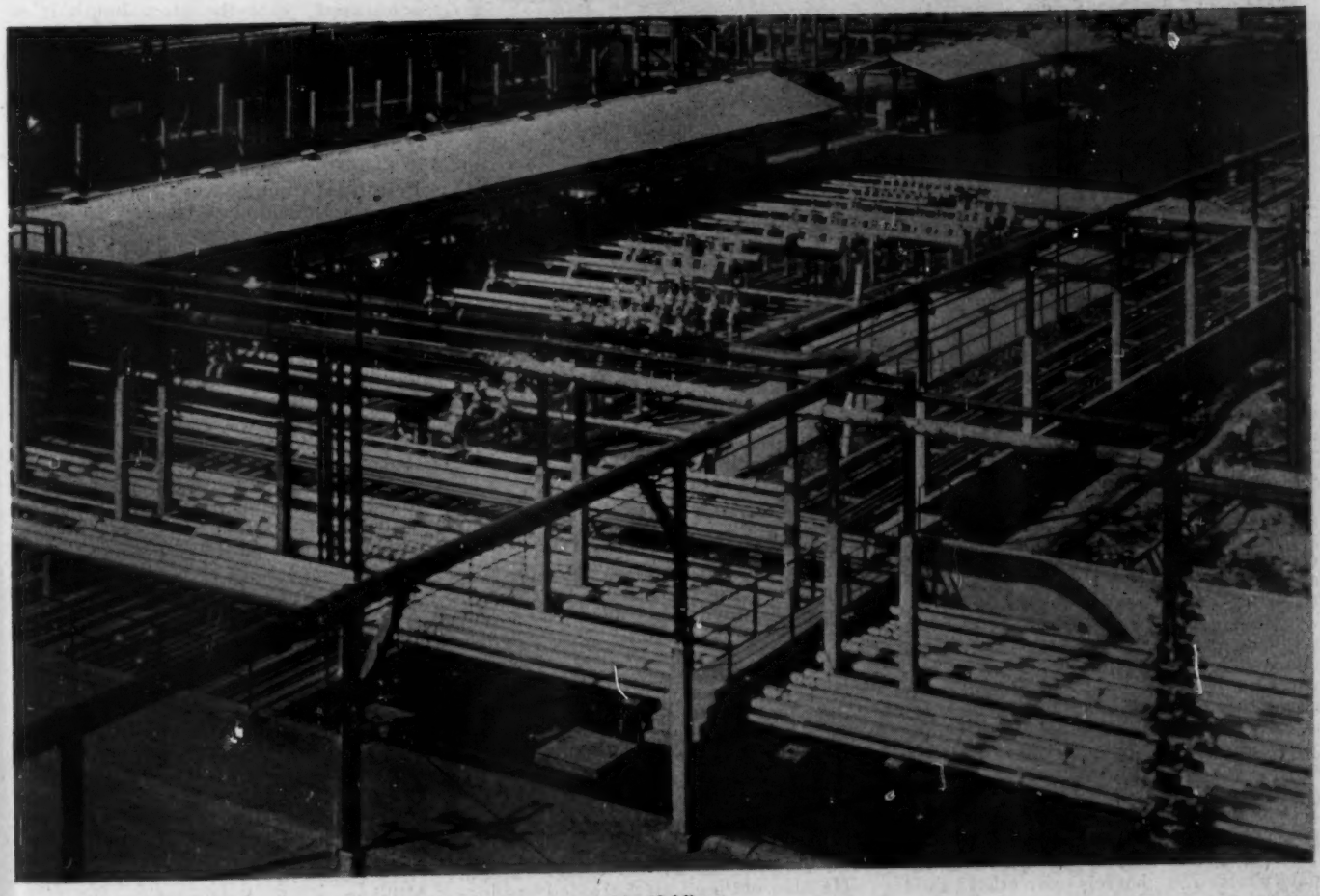
Below: The power plant.

—All photographs by S. Cortes Rubio.

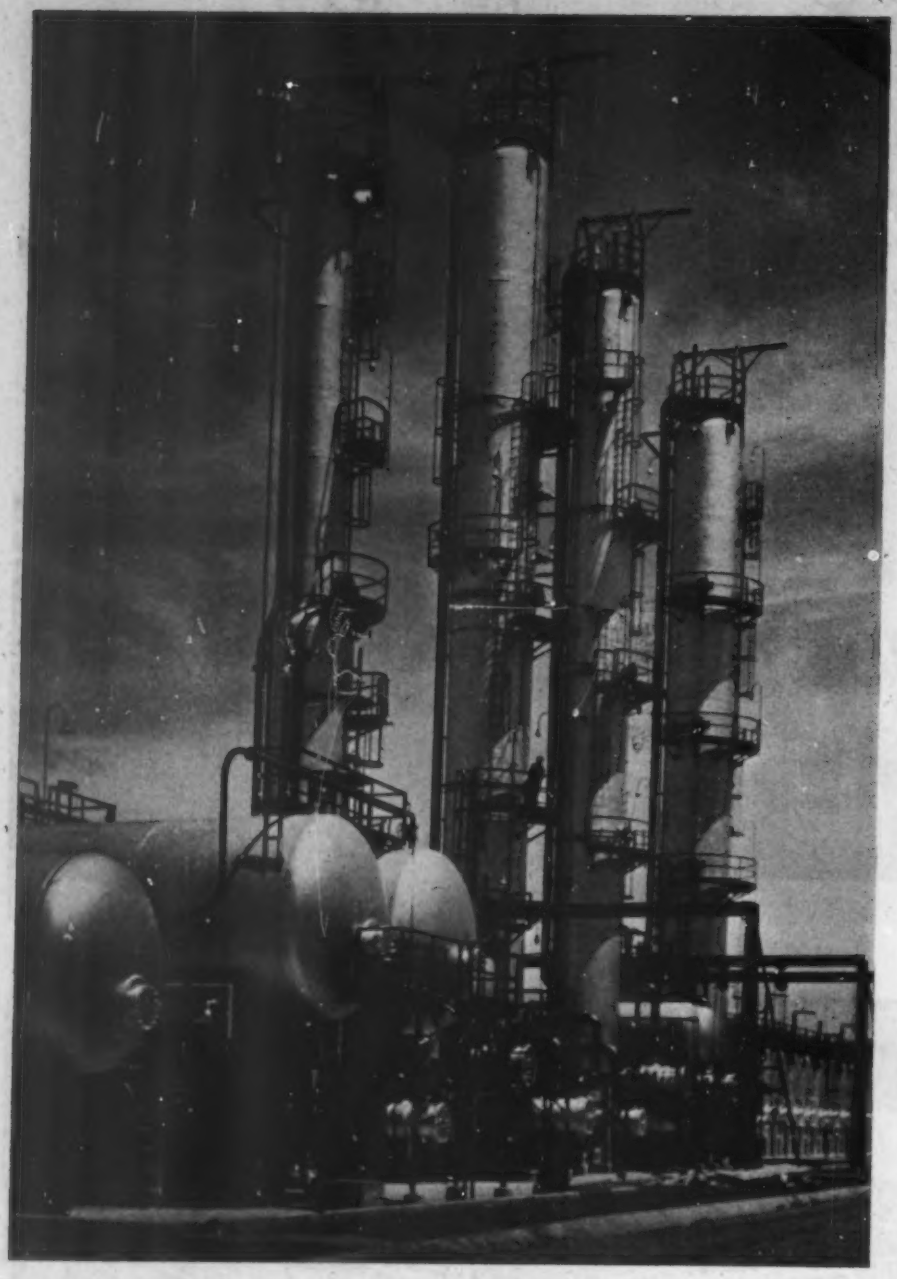




Desulphurization equipment



Manifolding



Light hydrocarbon fractionating unit, Petroleos Mexicanos refinery at Atzapotzalco.

capacity of 25,000 barrels per day, which is expected to operate at close to 40,000 barrels per day eventually; a fractionating unit for the production of isobutanes and isopentanes. This unit includes four towers 100 feet high and 11 feet in diameter, a depropanizer, a debutanizer, a deisobutanizer, and a deisopentanizer. Gas produced will be used to make liquefied petroleum gas, as charge for the alkylation unit, and for the preparation of aviation gasoline. A Perco treating unit to treat straight-run gasoline.

A thermal cracking unit of 13,000 barrels per day capacity equipped with a depropanizer, a debutanizer, and an absorption column. An alkylation unit capable of producing 900 barrels per day of alkylate high-octane blending stock. An isomerization unit with a capacity of 350 barrels per day.

A power installation consisting of two 5000-kilowatt steam turbine generators producing 60-cycle current.

A tetraethyl mixing plant with a capacity of 750 barrels of ethyl fluid per day.

Final refinery output is expected to be: 2000 barrels per day of 91-octane gasoline; 4500 barrels of 70-octane gasoline; 12,000 barrels of 45-octane gasoline, with final kerosine, gasoil, and fuel oil ratios according to the demand.

New Pemex Head Favors No Outside Oil Capital

Antonio J. Bermudez, recently was named director general of Pemex, the government-owned petroleum monopoly in Mexico, succeeding Efrain Buenrostro.

As head of Pemex, Bermudez will seek harmony between the government oil industry and its workers—a key to expanded Mexican industrialization promised by the new President Aleman.

The Mexican oil industry has been beset by frequent work stoppages.

Bermudez in a statement declared the Mexican oil industry would be developed without the aid of foreign capital.

He also outlined an increased production program designed to overcome the labor disturbances which have plagued Mexican oil and transportation operations. This would be financed by Pemex income and, failing sufficient profits for required expansion, he said, Mexican capital, both private and public, would be called on for assistance.

Beaumont Chemists Hear Report on Bikini Tests

Members of the Texas-Louisiana Gulf Section of the American Chemical Society met at Beaumont November 20 to hear Walter J. Murphy, editor of "Industrial and Engineering Chemistry" and "Chemical and Engineering News" speak on the Bikini atom-bomb tests. The meeting was conducted by V. A. Kalichevsky, chairman of the section. W. W. Leach, assistant general manager of the refining division of Magnolia Petroleum Company, made an address recounting the part played by petroleum chemists in the development of the industry. H. N. Frost, secretary of the section, gave a brief account of Murphy's professional experience, and introduced him to the group. Murphy discussed his experiences and observations as a press observer at the recent "Operation Crossroads" atom-bomb tests conducted at Bikini atoll, and presented a number of color slides which he made during the trip and the test periods, and a technicolor sound film of the tests which was filmed and released by the Navy. The slides and film gave enough detail of the actual explosions for the group to judge the energy release taking place and served to emphasize and amplify Murphy's statement that "I am very much a member of the league of frightened men," that the atom bomb is so powerful that the sane control of atomic energy is all important to civilization.

Committee to Nominate Council Officers Named

The next meeting of the National Petroleum Council will be held January 21 and thereafter quarterly in April, July and October.

A five-man committee has been named by temporary Chairman Walter S. Hallanan to consider nominations from the council for permanent chairman and vice chairman. The committee, which may report in January, includes R. G. Van Der Woude, president of Shell Union Oil Corporation, chairman; W. H. Ferguson, executive vice president of Continental Oil Company; B. L. Majewski, vice president of Deep Rock Oil Company; Charles F. Roeser, president of Roeser and Pendleton, Inc., and Reese H. Taylor, president of Union Oil Company of California.

AIME Elects C. E. Williams President for 1947

Clyde E. Williams, director of Battelle Memorial Institute, Columbus, Ohio, has been elected president of American Institute of Mining and Metallurgical Engineers for 1947. Andrew Fletcher, St. Joseph Lead Company, New York, and Robert W. Thomas, Nevada Consolidated Copper Corporation, Ray Arizona, were named vice presidents. Six directors elected included Oliver Bowles, A. J. Blair, W. W. Mein, Sr., C. V. Millikan, E. E. Schumacher and J. R. Suman. Dr. A. B. Parsons is secretary.

415½ days CONTINUOUS RUN—

A RECORD FOR FLUID CATALYTIC CRACKING UNITS

The Tidewater Associated Oil Company, at its refinery at Avon, California, has recently completed a run of 415½ days. This run of nearly 14 months continuous operation is a record for fluid catalytic cracking units.

During this period the unit processed approximately 8,000,000 barrels of fresh charge exclusive of recycle. Early in the run it was operated largely on straight run gas oil of 30° or higher A.P.I. gravity. At times various naphthas, both straight run and cracked, were charged as supplementary charge to maximize aviation gasoline production. Since the close of the war, the charge was gradually made heavier and for the past several months has been primarily a heavy California waxy distillate of high viscosity averaging 22° to 23° A.P.I. gravity.

Since the beginning of post-war operation, catalyst costs have averaged approximately two cents per barrel of fresh feed charged. Catalyst activity has been maintained at relatively high levels as indicated by the space velocities employed during the run.

This Tidewater unit is just one of the many fluid catalytic cracking units designed by Universal Oil Products Company.

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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by The Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

Phase Equilibria in Hydrocarbon Systems. H. H. Reamer, B. H. Sage, and W. N. Lacey. *Ind. and Eng. Chem.* **38** (1946) p. 986.

The volumetric behavior of four mixtures of n-butane and decane was experimentally determined at seven temperatures from 100° to 460° F. and for pressures up to 10,000 pounds per square inch. The results of the work establish the volumetric properties of the mixtures in the single-phase region for pressures greater than the bubble point. One mixture was studied at pressures low enough to permit the determination of the dew-point pressure and volume at 340°, 400°, and 460° F. The composition of the bubble point liquid at 100° and 160° F. for pressures below 30 pounds per square inch absolute was determined by making use of an equilibrium still. The results obtained in the work indicate that at the lower temperatures and higher pressures the system approaches the volumetric behavior of an ideal solution, but at the higher temperatures and intermediate pressures the volume can differ from ideal behavior by more than 50 percent. The purification of the hydrocarbons used in the work is described. The results are presented in tabular and graphical form in considerable detail. A bibliography of 13 references is included.

The Thermodynamic Function of Cyclohexane-Methanol Mixtures. Scott E. Wood, *Jour. Amer. Chem. Soc.* **68** (1946) p. 1963.

The changes of the free energy, enthalpy and entropy, on mixing at constant pressure, for the cyclohexane-methanol system were calculated from the measurements of the liquid-liquid equilibria reported by Eckfeldt and Lucasse. The excess changes of these functions over those of an ideal solution are all positive over the entire range of composition, except the entropy, which appears to become slightly negative in the rich methanol solution at 31° C.

The thermodynamic functions of the four systems, benzene-methanol, carbon tetrachloride - methanol, cyclohexane - methanol and chloroform-ethanol, are similar. The behavior of these systems is considered to be due to rather strong attractive forces operating between the unlike molecules. A relative estimate of these attractive forces between methanol and carbon tetrachloride, benzene or cyclohexane shows that they decrease in this order but that they are in general of the same magnitude.

Non-ideality in Some Binary Hydrocarbon Systems. C. B. Collis, *Nature* **157** (1946) pp. 845-6.

Solutions of paraffins and naphthenes were studied. It was found that azeotropes were formed and that the solutions exhibited marked non-ideality. The deviations from ideality were positive, and such that if an azeotrope formed it was of minimum-boiling type and the activity coefficients greater than unity. Azeotropes are formed between paraffins and cycloparaffins only when their boiling points are close together, for example less than 1°. Volume changes due to mixing at 20° are less than 0.1 percent.

Viscosities of Pure Hydrocarbons. J. M. Geist and M. R. Cannon. *Ind. and Eng. Chem., Anal. Ed.* **18** (1946) p. 611.

The method used in the determination of the viscosities of pure hydrocarbons is described. Detailed drawings of the viscometers used are presented. Tabular data are given for the viscosities of some 5-, 6- and 7-carbon hydrocarbons and for some 8-, 9- and 10-carbon hydrocarbons. Viscosities of the octanes are presented, and the viscosity of 2, 2, 4-Trimethylpentane is given over a temperature range. A bibliography of 6 references is included.

Chemical Composition and Reactions

Condensation of Acetylene by Molten Salts. Philip C. Johnson and Sherlock Swann, Jr., *Ind. and Eng. Chem.* **38** (1946) p. 990.

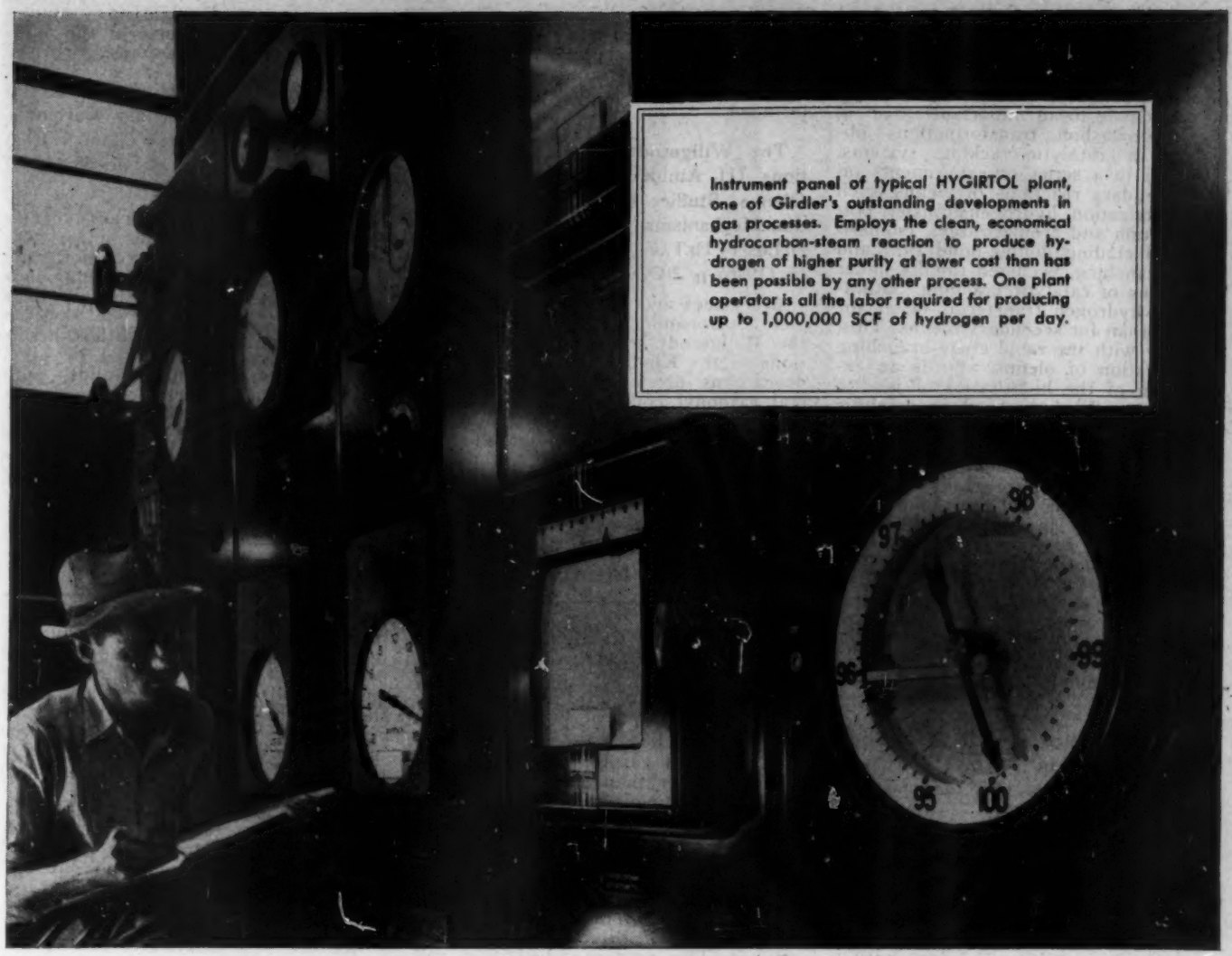
The polymerization of acetylene was studied because of the urgent need for benzene during the war. The most suitable reaction temperature lies between 600° and 700° C. Below 600° C. the reaction rate is too slow, and above 700° C. the spontaneous decomposition of acetylene to carbon and hydrogen occurs excessively. The principal reactions are exothermic and it is this kind of reaction that causes most of the difficulties. Local overheating in the catalyst bed can occur readily. Wetted wall columns with molten salt and gas in direct contact and passing countercurrent to each other proved successful in controlling the highly exothermic reaction in the condensation of acetylene to aromatic hydrocarbon liquids. Several salt systems, all of them halides, were investigated over a temperature range from 550° to 625° C. Acetylene-ethylene mixtures as well as pure acetylene were studied. Molten salts containing zinc chloride were found to catalyze the reaction as well as to serve as media for temperature control. Distillation of the products obtained under varying conditions of reaction showed that nearly identical fractions were obtained in each case. These fractions were similar to those obtained by previous investigators using higher reaction temperatures and carbon catalysts. The authors suggest that the results obtained indicate that fused salt systems could be used to replace to advantage the heat-exchange tubes commonly found in commercial catalyst beds. Results are presented in some detail in 4 tables and 3 figures. A bibliography of 21 references is included.

Chemicals Wanted

n-2-Octen-1-ol
2,6-Nonadien-1-al
2-Hexen-1-al di-Δ^3-hexenylacetal
Di-Δ^3-hexenylether
2-Hexen-1-al
Δ^2-Hexylenic acid
Δ^3-Hexylenic acid
2-Hydroxyhexyl aldehyde
4-Hydroxymethylazobenzene
Chlorobenzene-3,4-dithiol
1,3-Diamino-2-propanol
Tri isopropyl carbinyl borate
o-Iodoxynitrobenzene
m-Iodoxynitrobenzene
5-Amino-4-hydroxy-o-xylene
cis-2-Phenylcyclohexanol
trans-2-Phenylcyclohexanol
Phloretin
Pinastric acid
Octamethylene dibromide

Catalytic Cracking of Pure Hydrocarbons. H. H. Voge, G. M. Good, and B. S. Greensfelder, *Ind. and Eng. Chem.* **38** (1946) p. 1033.

Previous papers in this series describe the catalytic cracking of paraffins, olefins, napthenes and many aromatic hy-



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drocarbons of a variety of types and molecular weights. In addition to the primary cracking reactions involving a severance of carbon-to-carbon bond, several secondary reactions were shown to participate to an important extent in the hydrocarbon transformations observed in catalytic-cracking systems. This led to a series of experiments on the secondary reactions of olefins, such as isomerization, hydrogen transfer, polymerization and aromatization. Isomerization, including double-bond shift and chain-branching, occurred rapidly under conditions of catalytic cracking. Saturation by hydrogen transfer is faster for tertiary than for secondary olefins. This, together with the rapid chain-branching isomerization of olefins, affords an explanation of the high ratios of iso- to normal paraffins observed in catalytic cracking. Molecular hydrogen has no more influence than nitrogen on the saturation of olefins. Both act as inert diluents. Polymers are readily formed from lower olefins, but are rapidly converted to other products at the usual conditions for catalytic cracking. Such products from the treatment of normal butenes were found to include benzene, toluene, xylenes, and higher-boiling aromatic hydrocarbons in important quantities. Detailed data secured in the course of the work are presented in 12 tables. A bibliography of 12 references is included.

Role of Surface Area in Dehydrocyclization Catalysis. ALLEN S. RUSSELL AND JOHN J. STOKES, JR., *Ind. and Eng. Chem.* **38** (1946) p. 1071.

Activated aluminas were impregnated with different amounts of molybdena and their catalytic activities determined in the dehydrocyclization of n-heptane to toluene at atmospheric pressure. Activity was found to increase in a linear manner with added molybdena until a concentration dependent on the alumina area was attained. Excess molybdena beyond this amount did not further increase the catalyst activity. Activated aluminas of varying area were impregnated with constant amounts of molybdena and tested. It was found that the activity increased linearly with a surface area up to a value depending on the molybdena concentration. Further increase in area produced less rapid increase in activity. Comparison of the calculated molybdena area with the experimental value for maximum activity shows that the alumina surface is covered with a monolayer of molybdena at maximum activity. Activity was relatively insensitive to change in particle size in the range 2 to 20 mesh. The apparatus used in the work is illustrated and described. The data secured are presented in tabular and graphical form and a bibliography of 19 references is included.

Catalytic Dehydrogenation of Polycyclic Naphthenes. ARISTID V. GROSSE, JULIAN M. MAVITY, AND WILLIAM J. MATTOX, *Ind. and Eng. Chem.* **38** (1946) p. 1041.

The catalytic dehydrogenation of a series of polycyclic naphthenes in the presence of chromia-alumina catalysts was investigated. The chief reaction products were found to be aromatic hydrocarbons that resulted from the conversion of one or more six-membered naphthene rings to aromatic rings. Under the same conditions, paraffins of high molecular weight were cracked to a greater extent but produced relatively small quantities of aromatic hydrocarbons. A bibliography of 9 references is included.

The Willgerodt and Kindler Reactions. III. Amides from Acetylenes and Olefins; Studies Relating to the Reaction Mechanisms. MARVIN CARMACK AND DELOS F. DETAR, *Jour. Amer. Chem. Soc.* **68** (1946) p. 2029.

Acetylenes and olefins were found to yield carbonamides under conditions of the Willgerodt reaction. Under conditions of the Kindler reaction these hydrocarbons produced thioamides. Several carbonyl compounds were studied in the Willgerodt reaction. Isobutyl phenyl ketone, a typical branched-chain compound, gave a small amount of -methyl-phenylbutyramide with one reagent, but formed phenylacetamide with another reagent. Preliminary studies were made on the course of the Willgerodt and Kindler reactions.

The Willgerodt Reaction. IV. Acetylenes, Olefins, and Tertiary Carbinols. DEXTER B. PATTISON AND MARVIN CARMACK, *Jour. Amer. Chem. Soc.* **68** (1946) p. 2033.

The behavior of acetylenes, olefins, and two tertiary carbinols under conditions of the Willgerodt reaction were studied. All of the starting compounds produced carbonamides; the products usually had the same carbon skeleton as the starting compound, although side reactions involving the loss of alkyl groups and formation of amides with fewer carbon atoms were observed with several 1,1-disubstituted ethylenes. Thiosulfates and ammonium sulfite were found to improve the yields of the carbonamides when used in conjunction with the ammonium polysulfide reagent.

Manufacture: Process and Plant

Polytreating of Catalytically Cracked Gasolines. VLADIMIR HAENSEL AND V. N. IPATIEFF, *Ind. and Eng. Chem.* **38** (1946) p. 1045.

The mono-olefin components of thermally cracked gasolines have a higher octane number than the paraffinic and napthenic components and should not be removed in refining. Refining treatments should be designed for the removal of di-olefins, thus to decrease the tendency toward gum formation. The authors studied the treatment of first-pass catalytically-cracked gasolines in the presence of solid phosphoric acid catalyst. This process, which they call "polytreating," results in the formation of gasolines having a low olefin content and an increased lead susceptibility. The process operates at a temperature of 400° to 500° F. and at pressures in excess of 400 psig, with the preferred pressure about 600 pounds. The reduction in bromine number of a given gasoline is primarily a function of space velocity. Pressure has a small effect, provided the operation is conducted under sufficient pressure to maintain the liquid phase. The laboratory unit used in the work is illustrated and described. Detailed data are presented in 8 tables.

Estimating Chemical Engineering Equipment Costs. JOHN HAPPEL, ROBERT S. AIRES AND WILLIAM J. BORNS, *Chemical Engineering* **53** (1946) p. 99.

Economic studies covering processing plants are based on investment, operating costs, expenses, income tax and profit. These items are discussed by the authors and systematic procedures for their calculation are given. Previous articles on this general subject have been based on prewar costs, whereas higher prices will prevail for some time to come. Information given in the article is based on price levels as of September, 1946. Methods presented are particularly adaptable to the petroleum industry and to the manufacture of allied chemical products. Among equipment items covered are vessels, towers, heat exchangers, pumps and compressors, and piping. Procedure for estimating costs are given. Labor costs for erection are considered and in general given as a percentage of cost of the equipment to which the labor is applied. Consideration is given to alloy materials as well as to steel.

New Alloys for Severe Corrosion Services. M. G. FONTANA, *Chemical Engineering* **53** (1946) p. 114.

Two new corrosion-resistant alloys are described, Chlorimet 2, which is a nickel-molybdenum alloy, and Chlorimet 3, a nickel-molybdenum-chromium alloy. These materials are produced only as castings, and will probably find their largest use in pumps and valves. Both alloys are machinable, and Chlorimet 2 can readily be hardened by heat treatment. Data are presented covering the corrosion resistance of these alloys and information is given on hardening and heat treatment.

Products: Properties, Utilization, Analysis

Impurities in Petroleum Butadiene from Copper Salt Process. C. E. STARR, JR., AND W. F. RATCLIFF, *Ind. and Eng. Chem.* **38** (1946) p. 1020.

A substantial part of the butadiene produced during the war was derived from petroleum and it is expected that substantially all of it will be made from petroleum in the postwar period because of low cost. Butadiene has been used mainly for polymerization to rubber, but it offers numerous possibilities for organic syntheses. Commercial products contain 1,3-butadiene in excess of 98 percent. The impurities are chiefly hydrocarbons, individually occurring in concentrations of several tenths of one percent to trace quantities. The nature and extent of these impurities in butadiene refined by the copper-salt extraction process have been determined by

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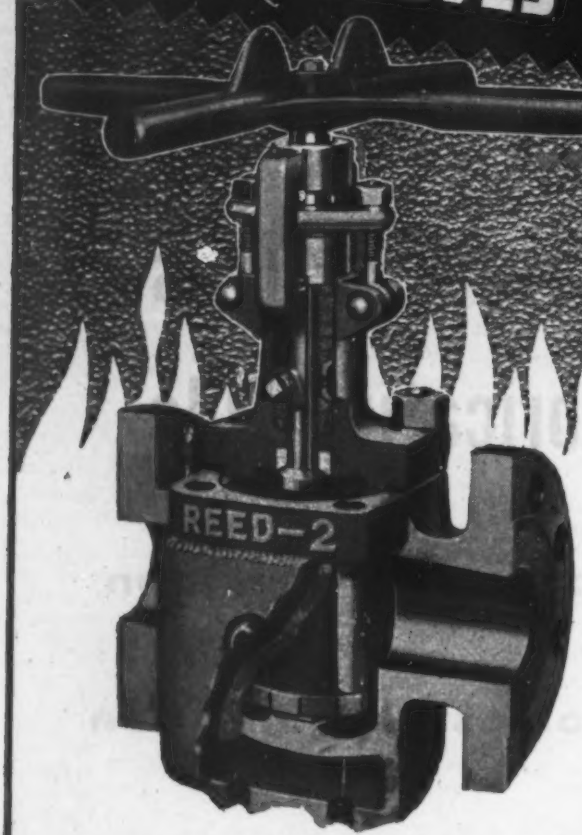

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application of mass and infrared spectrometric measurements. The principal impurities in petroleum-derived butadiene are the butenes, although smaller amounts of C_3 hydrocarbons are included. Detailed data are presented in 10 tables. A bibliography of 11 references is included.

On the Course of the Reaction at 100° C. in the System Aromatic-Free Mineral Oil/Oxygen. D. J. W. KREULEN, *Jour., The Inst. of Petroleum,* **32** (1946) p. 515.

The course of the oxidation at 100° C. in the system aromatic-free mineral oil/oxygen has been studied. A new apparatus for inspecting the oxidation of mineral oils under standard conditions is described. This procedure makes it possible to introduce oxygen into the oil at such a rate that real reaction velocities are measured. The data obtained were analysed with the aid of the Kreulen-Ter Horst method. The principles of this method are reviewed; it enables one to decide whether a substance is formed directly or following one or more intermediate stages. The formation of peroxide is apparently the first reaction stage, carbonyl-containing compounds the second, and acids the third. As the second reaction stage appears to a greater extent than the first reaction stage it is probable that the peroxides exert a catalytic action, or chain mechanism, during the oxidation. The saponification number increases during oxidation. It was found that this "saponification number" does not relate to esters or lactones but only to peroxides. A linear relationship between dipole moment and oxidation time was found, and is discussed and explained. A method of procedure is described that enables the accuracy with which the dielectric constant can be measured to be improved. This is based on the linear relationship found to exist between density and dielectric constant.

The Application of Variance Analysis to Some Problems of Petroleum Technology. H. M. DAVIES, *Jour., Institute of Petroleum,* **32** (1946) p. 465.

The importance of measuring variation in experimental data is emphasized and some methods of handling variable data and coping with variable conditions are described, and in particular the statistical technique developed by R. A. Fisher and known as the analysis of variance. The fluctuation of octane ratings is typical of the variation encountered in experimental work. The underlying statistical ideas are outlined along with the arithmetical procedures involved in variance analysis. To illustrate, 20 rich-mixture ratings by the British 3-C method are used as an example. These are first treated as two groups of ten results, and then as ten pairs of data, to show how the appropriate form of analysis depends on the way in which the results have been obtained. The randomized block arrangement, as illustrated by means of kerosine-burning-test results, secures the separation of major causes of differences, so that their effects do not interfere with the comparisons the experiment is designed to make. The Latin square arrangement carries this a stage further, giving control of error in two directions simultaneously. This method is illustrated by a test of the miles-per-gallon performance of seven motor fuels, and the ex-

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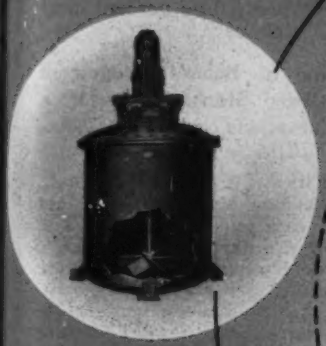

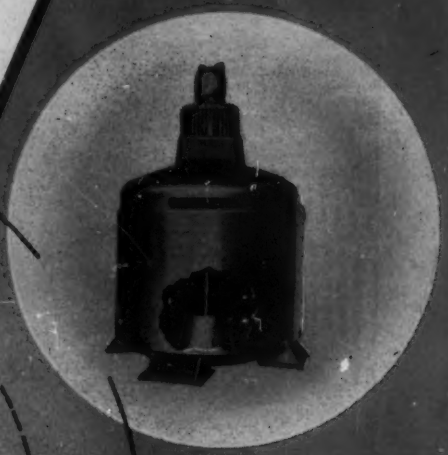

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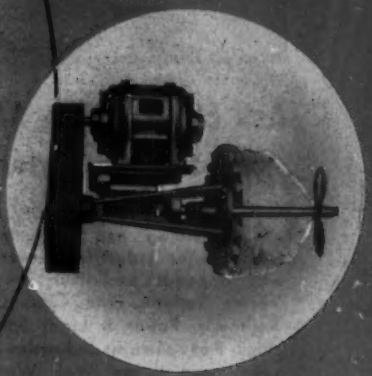

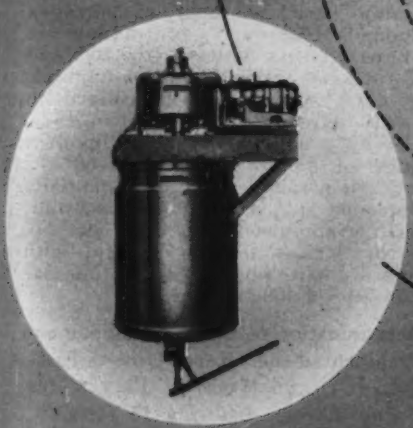

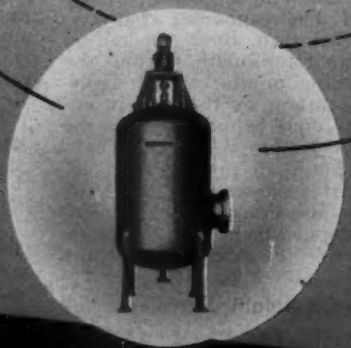

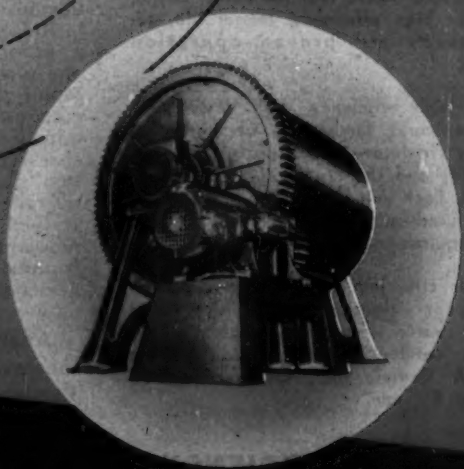

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ample is also used to introduce the idea of covariance. It is shown that the results themselves can be made to supply whatever correction is appropriate for the effect of a concomitant variate. Stress is laid on the unity of experiments, their plan, operation, analysis and final interpretation.

On the Course of the Reaction at 100° C. in the Systems Xylene/Oxygen and Aromatic-Free Mineral Oil/Xylene/Oxygen. D. J. W. KREULEN, *Jour., The Institute of Petroleum* **32** (1946) p. 525.

The oxidation of xylene and solutions of xylene in aromatic-free mineral oil was studied. The formation of peroxides and aldehydes in each is linear with respect to time, whereas acid formation appears to increase with the square of the time. A gradual change in oxidation behaviour with increasing percentage of one of the components was observed when treating mixtures of xylene and aromatic-free oil. In this instance purer aldehydes were formed than would have been expected. This is explained by a retardation effect. If copper is present, the peroxides are destroyed during the oxidation and a corresponding increase in aldehydes is found. In the case of the oxidation of pure xylene an insoluble cuprous salt of toluic acid settles from the reacting liquid.

Vapor-Liquid Equilibrium Still for Miscible Liquids. DONALD T. C. GILLESPIE, *Ind. and Eng. Chem., Anal. Ed.* **18** (1946) p. 575.

A new type apparatus is described for the determination of vapor-liquid equilibrium data. It comprises an electrically heated still fitted with a Cottrell pump, a vapor-liquid disengagement chamber, and a condensate trap. Both the boiling liquid and vapor circulate within the apparatus. Boiling points can be determined with accuracy, as the system ensures complete equilibrium between the two phases. A simple test for the entrainment of liquid in the vapor is described, and it is shown that with the new apparatus less than 0.05 percent entrainment occurs, which has, therefore, a negligible effect upon the equilibrium data.

Analysis of Oil-Soluble Petroleum Sulfonates. FRANCIS BROOKS, EDWARD D. PETERS, AND LOUIS LYKKEN, *Ind. and Eng. Chem., Anal. Ed.* **18** (1946) p. 544.

In the acid treatment of petroleum distillates sulfonic acids are formed, some of which are soluble in the oil layer and others soluble in the water or acid layer. The former are frequently called "mahogany" acids, while the water-soluble acids are called "green" acids. The authors present an extraction-adsorption method for the analysis of the oil-soluble petroleum sulfonates. The method is applicable to the analysis of sodium and other metal sulfonates and is free from lengthy operations and difficulties with emulsions. Procedures are given for the determination of mineral oil, sulfonic acid soap, water, carboxylic acid soap, free alkali, and inorganic salts.

Determination of Conjugated Diolefins with Chloromaleic Anhydride. S. T. PUTNAM, M. L. MOSS, AND R. T. HALL, *Ind. and Eng. Chem., Anal. Ed.* **18** (1946)

The authors describe a new method for determining conjugated diolefins in hydrocarbon mixtures. The method is based on the utilization of chloromaleic anhydride as the dienophilic reagent. Chloromaleic anhydride adds quantitatively to conjugated dienes to form an addition product containing a highly reactive tertiary chlorine atom that can be determined by the Volhard method after refluxing with aqueous silver nitrate. The vinyl chlorine of the reagent is completely unreactive under the same conditions. The method was applied to standard samples of isoprene, isoprene-amylene, isoprene-pentane, cyclopentadiene, and butadiene. The results given indicate that the average error of the determination expressed as percent conjugated diene is about 0.5 unit.

Determination of Basic Nitrogen in Hydrocarbon Feed Stocks. LEON DONN AND HARRY LEVIN, *Ind. and Eng. Chem., Anal. Ed.* **18** (1946) p. 593.

Trace impurities in hydrocarbon gases may have a serious and harmful effect upon certain catalytic processes. The present paper describes a suitable method for determination of ammonia or other basic nitrogen compounds. Ammonia is not absorbed when very dilute gaseous concentrations of the gas are bubbled through dilute sulfuric acid. Storage of such dilute gaseous mixtures in iron cylinders results in loss of appreciable basic amounts of nitrogen compounds. Ammonia and amines in concentrations between 0.000015 and 0.008 percent, calculated as ammonia, have been successfully determined in normally gaseous hydrocarbon feed stocks by a new method that involves passage of a cooled (about —60° C.) hydrocarbon sample into a substantially nonaqueous standard solution of sulfuric acid, evaporation of the hydrocarbon, and titration of the excess acid with standard alkali. About 4 hours time are required for a 400-gram sample.

Determination of Cyclopentadiene and Dicyclopentadiene. KARL UHRIG, ELEANOR LYNCH, AND HARRY C. BECKER, *Ind. and Eng. Chem., Anal. Ed.* **18** (1946)

Determination of cyclopentadiene is difficult because of the instability of the compound. It polymerizes to rubberlike materials with the aid of a catalyst, and it also dimerizes spontaneously even at room temperature. The rate of dimerization increases with temperature. However, if the temperature is raised to about the boiling point of dicyclopentadiene (170° C.) the reaction is reversed and the dimer changes to monomer. Thus it is necessary to determine both the monomer and dimer. Cyclopentadiene in a C_5 fraction is determined by condensation with benzaldehyde to form highly colored phenylfulvene, the intensity of the color of which is a measure of the cyclopentadiene present. None of the materials normally associated with it in hydrocarbon samples interferes. Oxidation inhibitors must be absent. Since cyclopentadiene dimerizes rapidly even at ordinary temperatures, the average C_5 fraction will contain both the monomer and dimer. The latter represents available cyclopentadiene because it can easily be depolymerized, and the method described for its determination is a valuable supplement to the method for determining the monomer. The dimer is determined by controlled depolymerization to the monomer, which is determined colorimetrically. Cyclopentadiene originally present as such is determined separately.

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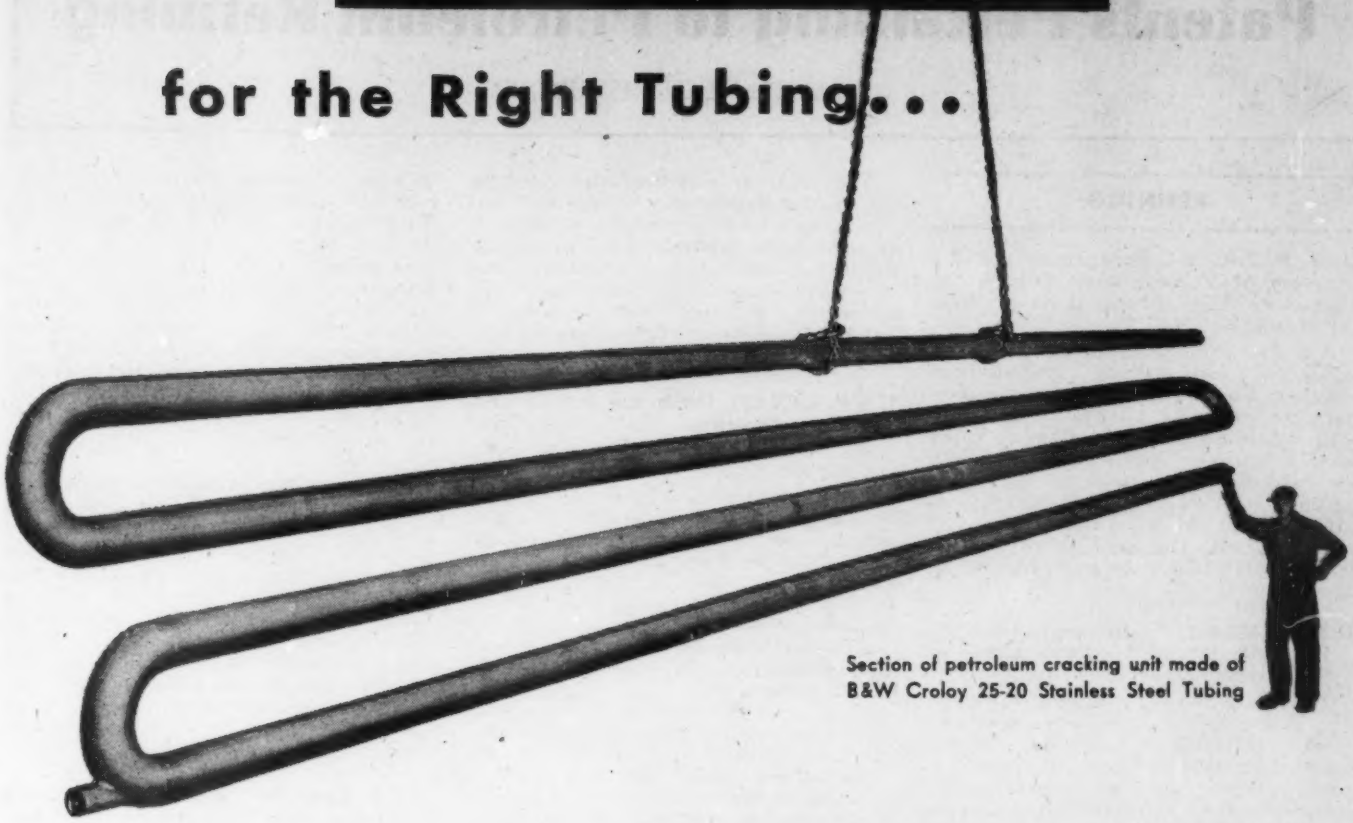

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Digest of Recently Issued United States

Patents Pertaining to Petroleum Refining

Compiled by HEINZ HEINEMANN

REFINING

U. S. P. 2,407,364. Process for the Recovery of Toluene from Oils. C. R. Clark to Allied Chemical & Dye Corporation.

A hydrocarbon fraction containing toluene and non-aromatic hydrocarbons which ordinarily boil in the same temperature range as toluene is azeotropically distilled in the presence of the methyl, ethyl, or butyl ethers of ethylene glycol. The non-aromatic hydrocarbons are vaporized with the ethylene glycol ether and a residue enriched in toluene is left. The treated hydrocarbon fraction preferably has an end point not above 118° C.

U.S.P. 2,407,492. Production of Gasoline. L. G. Hall and H. G. Boucher to Shell Development Company.

Gasoline comprising straight-run gasoline and cracked gasoline is produced from petroleum by separating from a cracked gasoline an olefinic fraction consisting largely of C_6 hydrocarbons, and substituting a saturated straight-run-gasoline fraction consisting largely of C_6 and C_7 hydrocarbons. The thus produced blend is subjected to a hydrofining treatment under hydrogen pressure in the presence of a hydrogenation catalyst. The separated olefinic fraction is subjected to acid refining and the thus refined material is recombined with the hydrofined blend. A hydrocarbon oil cracked with a clay-type catalyst can, for example, be employed as the cracked-gasoline feed. The hydrofining operation can be carried out with a metal-sulfide catalyst at 850-1000° F.

U.S.P. 2,407,716. Superfuel. R. F. Marschner to Standard Oil Company (Indiana).

The fuel which can be used as an aviation superfuel is composed of a mixture of 30-90 percent by volume of cyclopentane, free from n-pentane, and neohexane. It has a boiling range of 120-124° F., a refractive index above 1.38, A.P.I. gravity below 75, and an octane number above 95 C. FR-R. A commercial isooctane having a 10 percent point of about 200° F. and a 90 percent point of 230-270° F. may also be blended with said composition.

U.S.P. 2,407,717. Aviation Superfuel. R. F. Marschner to Standard Oil Company (Indiana).

This invention relates to an aviation combat fuel which shows both a high supercharge octane number and a high rich mixture response. The fuel comprises a blend of 40-80 percent commercial isooctane and 60-20 percent of 1,1,2-trimethylcyclopropane.

U.S.P. 2,407,718. Aviation Superfuel. R. F. Marschner and D. R. Carmody to Standard Oil Company (Indiana).

The aviation superfuel described in this patent essentially comprises isooctane and 10-40 percent by volume of an azeotropic mixture. This azeotropic mixture is composed of propanone and either neohexane or cyclopentane or diisopropyl; it may also consist of butanone and either cyclohexane or benzene or trimethylbutane.

U.S.P. 2,407,825. Producing and Concentrating Diolefins. F. E. Frey and R. D. Snow to Phillips Petroleum Company.

Aliphatic conjugated diolefins are continuously separated from admixture with other close-boiling more saturated hydrocarbons by continuously feeding the charge mixture and ½ - 3 times its weight of SO_2 to a reaction zone where a temperature of 60-80° C. is maintained. The amount of SO_2 employed is in excess of that molecularly equivalent to the diolefin present. The mixture of hydrocarbons and SO_2 is heated under sufficient pressure to maintain liquid phase. All free diolefin is converted to the monosulfone while the formation of hetero-polymeric products is prevented by continuously maintaining in the reaction zone a branched-chain monoolefin having the same number of C atoms per molecule as the treated diolefin. The amount of the monoolefin used corresponds to 2-10 percent of the total hydrocarbons present. The reacted mixture is continuously removed from the reaction zone and resolved into sulfone and unreacted materials. Butadiene may, for example, be obtained in this manner, and isobutylene or unsym.-methyl ethel ethylene may be employed for suppressing the formation of heteropolymeric products.

U.S.P. 2,407,861. Process of Treating Hydrocarbons. I. L. Wolk to Phillips Petroleum Company.

A liquid polymerizable organic compound is subjected, while in a fractionation zone, to conditions favorable to oxidation. An oxidation inhibitor, nonvolatile under conditions of distillation, is introduced into this zone in an amount sufficient to inhibit oxidation and polymerization of the treated compound in the liquid state. A second oxidation inhibitor more volatile than the treated compound is continuously introduced into the treating zone in an amount sufficient to inhibit oxidation and polymerization in the vapor state. In the treatment of a styrene-containing mixture, for example, phenyl-beta-naphthylamine can be used as the inhibitor of less volatility, and ammonia, hydrogen sulfide, aliphatic amines, or the like as the volatile inhibitor.

U.S.P. 2,407,997. Separation and Purification of Isoprene. J. A. Patterson to Standard Oil Development Company.

A cracked hydrocarbon stock containing isoprene is distilled in the presence of aqueous acetone. An azeotropic mixture containing isoprene is obtained as distillate. The distillate is extractively distilled in the presence of a solvent comprising acetone. The distillate fraction containing isoprene in high concentration is fractionated to obtain pure isoprene. Other stable organic liquids of high dielectric constant, such as furfural, pyridine, the amines, and their admixtures with water, may be used in place of acetone as the solvent in the extractive distillation.

U.S.P. 2,408,011. Method for Preventing Corrosion of Distillation Equipment. D. C. Walsh, Jr., and E. Q. Camp to Standard Oil Development Company.

Hydrocarbons, such as alkylates, which have been contacted with or formed in the presence of sulfuric acid are mixed with a small amount (0.005 to 5 percent) of an alkali salt of a phenol immediately prior to their distillation. The corrosivity and fouling tendency of the hydrocarbons is substantially eliminated.

U.S.P. 2,408,173. Treatment of Aromatic Hydrocarbon Materials. M. P. Matuszak to Phillips Petroleum Company.

Aromatic hydrocarbons containing organic fluorine compounds are contacted with liquid hydrofluoric acid. The relative amounts of hydrocarbon and HF and the contacting temperature are correlated so as to insure the presence of a liquid hydrocarbon phase and of a liquid hydrofluoric acid phase. The resulting hydrofluoric acid extract is separated from the hydrocarbon material. An appreciable amount of a liquefied paraffin with 3-5 C atoms is added to the extracted hydrocarbon material. The resulting mixture is fractionated to remove the added paraffin and hydrofluoric acid which has remained dissolved in the hydrocarbon material. The organic fluorine compounds of the starting material are soluble in hydrofluoric acid and are removed with the hydrofluoric acid extract.

U.S.P. 2,408,922. Separation of Diolefin by Azeotropic Distillation. T. W. Evans, R. C. Morris and E. C. Shokal to Shell Development Company.

Acyclic diolefins of 5 C atoms, such as isoprene or piperylene, are concentrated or separated from mixtures thereof with one or more mono-olefins or paraffins, the vapor pressures of which are close to those of the diolefins, by adding isopropylamine to the mixture in an amount at least sufficient to form minimum-boiling azeotropic mixtures with each of the components thereof. The resulting mixture is fractionated to obtain a plurality of overhead fractions progressively richer in the acyclic diolefins. If the amount of isopropylamine added is only sufficient to form azeotropes with the component of the mixture other than diolefins, the

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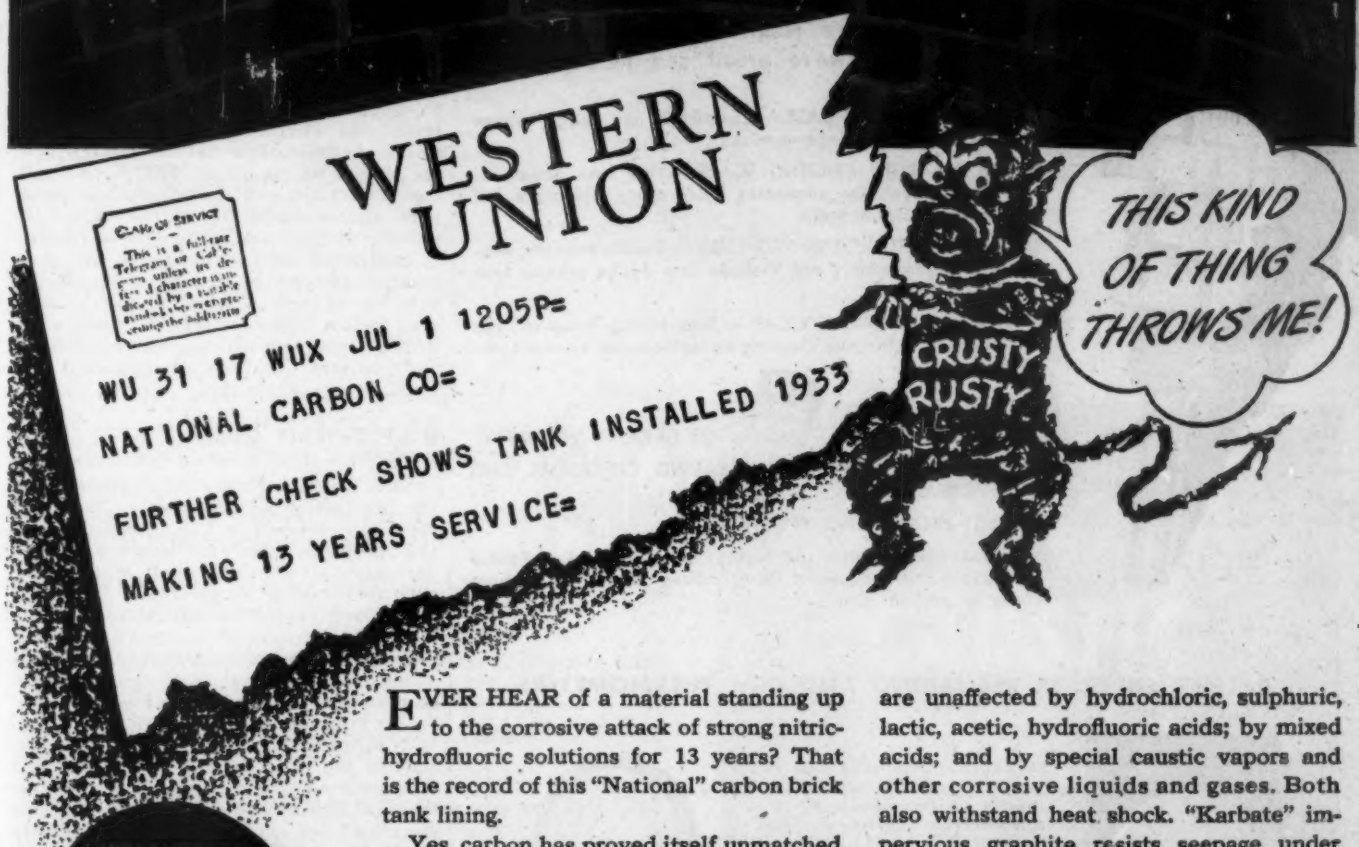
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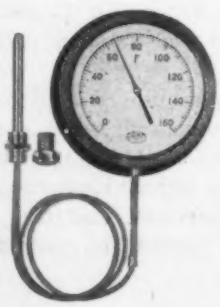

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latter are predominant in the residue from the subsequent fractionation.

CATALYST PREPARATION ACTIVATION AND REGENERATION

U.S.P. 2,407,374. Catalytic Cracking Process. C. H. Kollenberg to Standard Oil Development Company.

In the regeneration of a cracking catalyst by hot combustion gas the bulk of the regenerated catalyst is returned to the cracking stage while the combustion gas which carries finely divided catalyst is conducted to an electrical precipitator stage. The regeneration stage is maintained at a higher absolute pressure than the precipitator stage. The finely divided catalyst is separated from the combustion gas in the precipitator stage and mixed with feed oil to form a slurry which is introduced into the cracking stage.

U.S.P. 2,407,813. Process for Manufacture of Supported Catalyst. H. A. Cheney to Shell Development Company.

Catalysts which are particularly effective in the conversion of olefinic hydrocarbons to their lower-boiling linear polymers are produced by admixing aqueous cobalt nitrate with activated carbon in a closed vessel, applying heat to the vessel under controlled conditions and effecting a gradual increase in the temperature of the contents of the vessel up to about 400° C. Volatilized materials and decomposition products are removed from the vessel as rapidly as they are formed. The heating is continued until evolution of any substantial amount of decomposition products has ceased. A subatmospheric pressure below 150 mm. Hg is maintained in the vessel during the mixing, heating and cooling. Catalysts of improved uniformity are obtained.

U.S.P. 2,407,814. Catalysts. H. A. Cheney to Shell Development Company.

This patent relates to a process for the production of catalysts of the same kind as described in U.S.P. 2,407,813. In the present case the mixture of an aqueous solution of cobalt nitrate and activated carbon is gradually heated in the closed vessel to only about 110° C. Water is introduced in successively decreasing amounts into the vessel while volatilized material and gaseous decomposition products are removed therefrom. Heating in the presence of water is continued, until at least a substantial part of the cobalt nitrate is decomposed. Thereafter heating is continued without further addition of water at higher temperatures not exceeding 400° C. until the evolution of decomposition products ceases.

U.S.P. 2,408,140. Dehydrogenation Catalyst. C. L. Gutzeit to Shell Development Company.

The catalyst employed in the process described in U.S.P. 2,408,139 is produced by intimately mixing powdered Fe_2O_3 with powdered Cr_2O_3, forming a paste with an aqueous solution of a potassium salt, extruding the paste, drying the pellets formed and calcining them at 800-950° C. under conditions under which no appreciable formation of iron chromite takes place and for a time sufficient to decrease the available sur-

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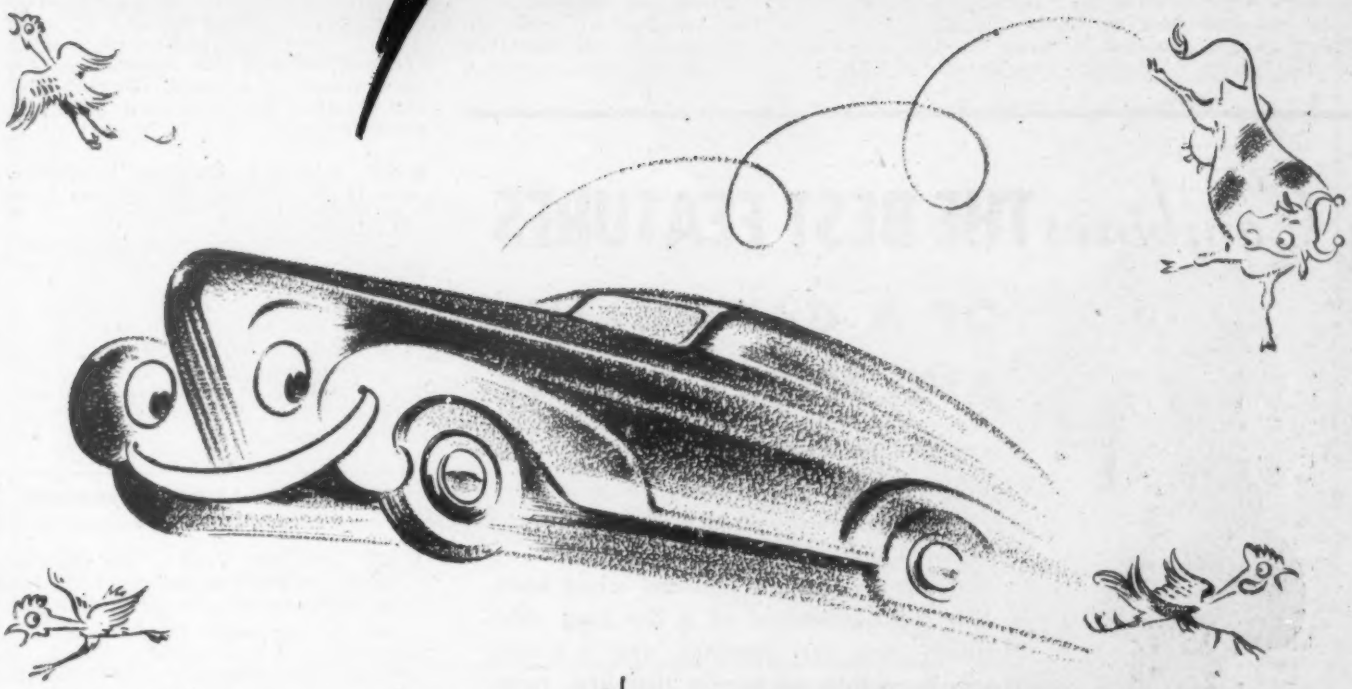

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U.S.P. 2,408,164. Catalyst Preparation. A. L. Foster to Phillips Petroleum Company.

A substantially rugged and pervious mass of a solid Friedel-Crafts metal-halide catalyst, as used in hydrocarbon conversion processes, is formed by heating a particulate mixture comprising solid particles of such a metal halide, and containing at least 20 percent by volume of inter-particle voids, to a temperature below the melting point of the components of this mixture. The mixture while maintained at this temperature is subjected to mechanical pressure just sufficient to effect incipient fusing of the particles of metal halide at their points of contact without substantially melting or disintegrating them and without substantial reduction of the void volume.

U.S.P. 2,408,187. Catalyst Manufacture. H. V. Atwell to The Texas Company.

A stream of saturated aliphatic C_4 hydrocarbons in liquid phase is circulated through a catalyst zone containing $AlCl_3$ in solid granular form. The conditions of temperature and time of contact are chosen so that a small amount of $AlCl_3$ is dissolved in C_4 hydrocarbons without substantial complex formation. The circulating stream containing dissolved $AlCl_3$ is then passed to a reaction zone. A small amount of kerosine is added to the stream, and the mixture is treated in the presence of hydrogen halide at elevated temperature, dissolved $AlCl_3$ reacting with kerosine to form a complex. The resulting complex is separated from the unreacted hydrocarbons including C_4 hydrocarbons, and these hydrocarbons are recycled to the contact zone. The temperature in the contact zone is preferably maintained below 200° F. and that in the reaction zone at 200-300° F.

U.S.P. 2,408,207. Treatment of Clay. A. D. Garrison and K. C. ten Brink to Texaco Development Corporation.

An activated, non-swelling clay containing montmorillonite is converted into a swelling clay by adding to a dispersion of the clay in water sodium carbonate in an amount sufficient to raise the pH to at least 8.5. Silica gel is added to the highly dispersed and hydrated clay. The resulting composition is acidified, and the acid clay material containing the silica gel is dried. The clay product obtained has improved adsorptive characteristics.

U.S.P. 2,408,215. Catalyst Production. G. H. Keating to The Texas Company.

A major proportion of an inorganic catalyst gel, such as a silica-alumina gel, is mixed while in the moist and hydrated state and before removal of water of hydration, with 30-60 percent (based on dry gel) of a starch material adapted to form a plastic composition with water. The plastic mass obtained is extruded, dried and calcined to remove the organic material.

CRACKING AND REFORMING

U.S.P. 2,407,700. Process for the Conversion of Fluid Reactants. L. C. Huff to Universal Oil Products Company.

For the conversion of fluid reactants, particularly for catalytic cracking, reforming, dehydrogenation, dehydrocyclization, or aromatization of hydrocarbons, subdivided solid contact material is passed downwardly in the form of a relatively compact continuous column extending uninterruptedly from an uppermost separating zone through and between a plurality of superimposed contacting zones. The static pressure at the bottom of the column must be substantially greater than the pressure in the uppermost zone. The reactant, such as a hydrocarbon oil, is contacted under conversion conditions with the solid material in one of the zones, maintaining the pressure of the vaporous conversion products therein substantially higher than the pressure in the separating zone. The solid material is regenerated in another of the contacting zones by an oxygen-containing gas stream. The solid particles are discharged from the bottom of the column into a stream of transporting fluid comprising vaporous conversion products of the reactant. The suspension is passed to the separating zone solely by the gas-lift action of the transporting fluid. The solid particles are separated from the transporting fluid in the separating zone and deposited onto the top of the column in the separating zone.

U.S.P. 2,407,817. Converting Hydrocarbons. A. V. Danner to Socony-Vacuum Oil Company.

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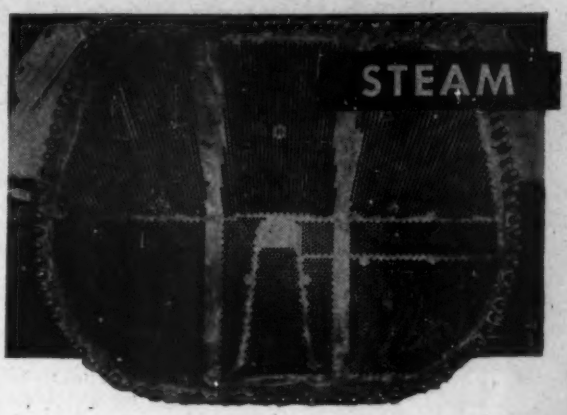

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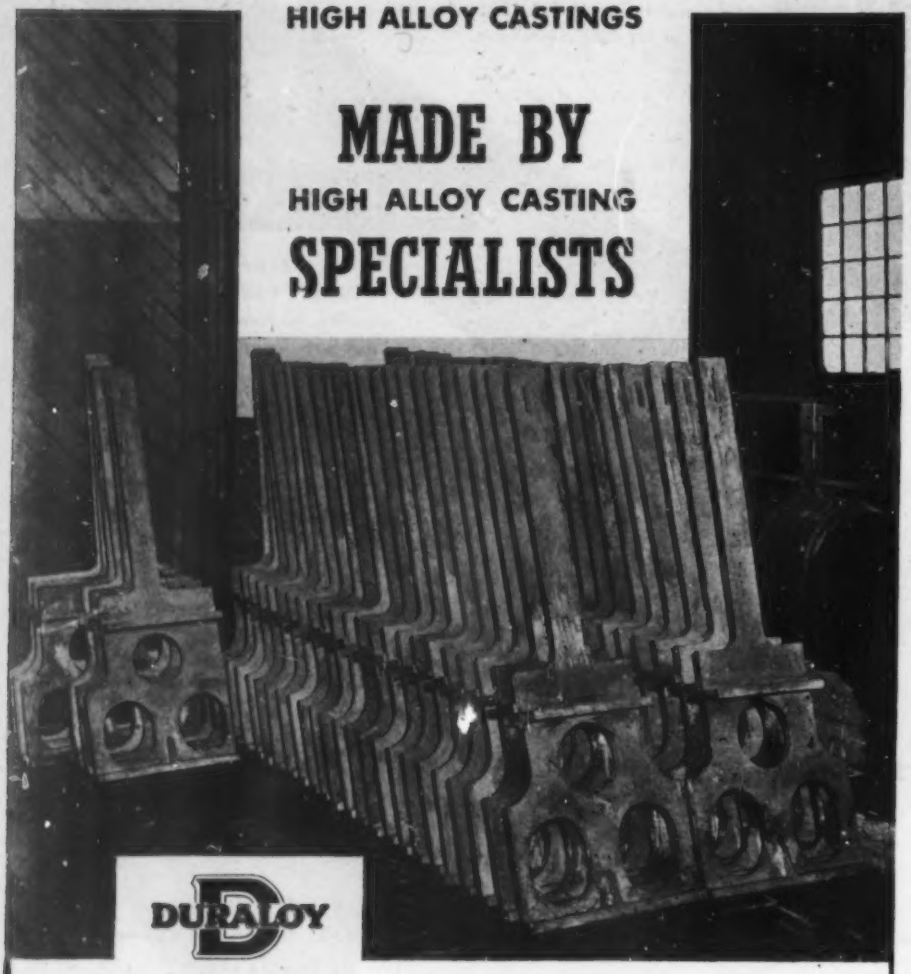

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tion is converted to gasoline and another portion to olefins. The reaction is carried out in the presence of a solid adsorptive-contact mass, such as silica-alumina, maintained in suspension in the charge. The cracking products are separated into vapors and a liquid fraction containing the suspended solid. The vapors are fractionated into an olefin-containing fraction, a gasoline, and a heavier-than-gasoline fraction. The olefin fraction is converted in the presence of a solid catalyst of the same type as used before to a material of gasoline boiling range. The vaporous products of this conversion are passed to common fractionation with the vapors of the first cracking operation. The contact mass is removed from the olefin conversion stage and introduced to the hydrocarbons in the first cracking operation.

U.S.P. 2,407,918. Catalytic Conversion of Carbonaceous Materials. J. Burgin to Shell Development Company.

Carbonaceous material, such as hydrocarbon oil, is catalytically converted, e.g., cracked, isomerized, or reformed, at elevated temperature in the presence of a catalyst consisting of a minor amount of boric oxide and a major amount of a relatively inert catalyst carrier. The carbonaceous material is subjected in a fluid state to contact with the catalyst. A mixture of steam and boric acid is passed through the reaction zone along with the fluid carbonaceous reactant to inhibit a decline in the catalyst activity.

U.S.P. 2,408,580. Hydrocarbon Conversion Process. D. Read, Jr., to Universal Oil Products Company.

The charge oil is fractionated in contact with cracked vapors to form a relatively heavy fraction and a lighter fraction. The heavy fraction is thermally cracked. The cracked vapors obtained are separated from residual products. A cracking catalyst is mixed with a portion of said lighter fraction. The mixture formed is subjected to cracking conditions and the cracked product is quenched by mixing it with another portion of said lighter fraction. The mixture is separated into vapors and catalyst-containing residue. The vaporous products of the catalytic cracking and vaporous products of the thermal cracking are charged to the fractionating step.

U.S.P. 2,408,584. Hydrocarbon Cracking Process with Successive Additions of Adsorbent. A. D. Smith to Jenkin Petroleum Process Company.

Successive increments of a finely divided hydrous mineral adsorbent having the characteristic of gradually liberating its structural water when heated to oil-conversion temperature are supplied to an oil stream undergoing heating. Each increment is added at about the time at which the previous increment ceases to liberate structural water. Calcium hydroxide is the preferred adsorbent. The adsorbent reacts with corrosive compounds generated by decomposition of ingredients of the treated oil, minimizing corrosion in the cracking still.

U.S.P. 2,408,600. Cracking Process. C. H. O. Berg to Union Oil Company of California.

A granulated catalyst is passed by gravity flow through successive zones of reaction and regeneration. Hydrocarbons are passed countercurrently to the catalyst through the reaction zone main-

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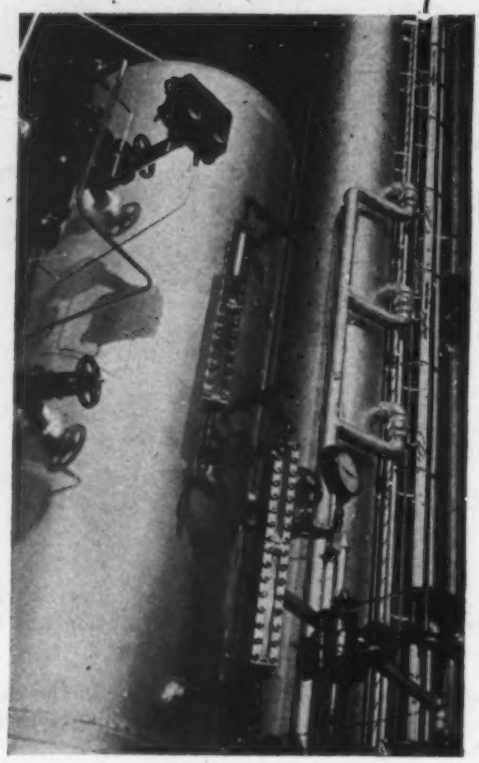

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tained at an elevated conversion temperature. Regenerated catalyst is withdrawn from the regeneration zone. The withdrawn catalyst is suspended in a gas to lift it and pass it to a separating zone, where it is separated from the gas and from where catalyst is passed to the reaction zone. The separated suspension gas, which may comprise hydrogen or hydrocarbon feed, such as light hydrocarbon gases, is introduced to the reaction zone along with the hydrocarbons to be treated.

ISOMERIZATION

U.S.P. 2,407,231. Moisture Removal in Isomerization Processes. L. S. Galstaun to Tide Water Associated Oil Company.

A stream of liquid hydrocarbons containing dissolved HCl and water is introduced to the top of a fractionating column. HCl is stripped from the hydrocarbons under conditions of temperature and pressure such that the water is retained in the column. A minor portion of the downward stream is withdrawn from a zone intermediate the ends of the column where the concentration of water is greater than in the entering stream, so that the concentration of water in the column is held below a degree of substantial separation. A temperature of 110° F. and a pressure of 275 psi may be maintained in the intermediate zone. The volume of the withdrawn side-stream is 0.2-5 percent of the volume of the entering stream. The process can be used in the isomerization of hydrocarbons in the presence of $AlCl_3$ and HCl.

U.S.P. 2,407,488. Isomerization Process. W. B. Franklin to Standard Oil Development Company.

A normal paraffin with at least 4 C atoms is continuously fed in admixture with promotional amounts of hydrogen halide to a catalyst comprising a porous support carrying aluminum halide maintained under isomerizing conditions. Whenever a decrease in catalyst activity requires it, the hydrogen halide in the feed mixture is replaced by anhydrous aluminum halide without altering the conditions of operation. This treatment is continued for a sufficient period to effect a substantial restoration of the catalyst activity.

U.S.P. 2,407,637. Production of Branched-Chain Alkanes. E. W. M. Fawcett to Anglo-Iranian Oil Company, Ltd.

A normal alkane-containing stream is continuously passed in vapor phase over a solid unsupported aluminum halide catalyst maintained at a catalyst vaporizing temperature, preferably exceeding 132° C., to effect a continuous evolution and transfer of catalyst vapors to said stream. The flow rate is so controlled that the concentration of the catalyst in the stream does not exceed a concentration equivalent to the saturation pressure of the catalyst at the isomerization temperature of less than 200° C. The stream containing catalyst vapor and a small proportion of hydrogen halide promoter is passed at isomerization temperature through a reaction zone which contains a bed of solid highly porous adsorptive material essentially free of catalyst in a condensed form. The branched-chain alkane product is re-

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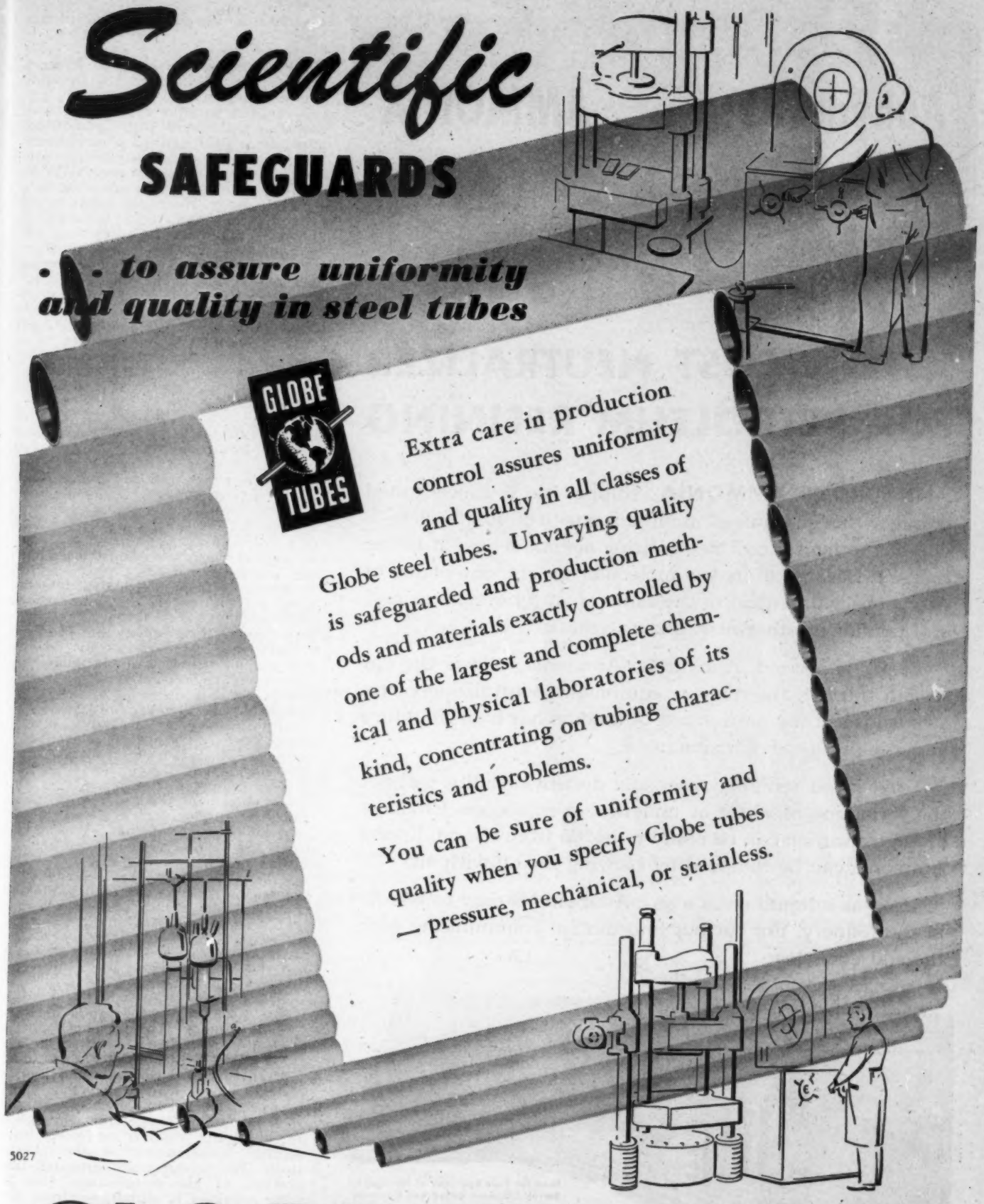

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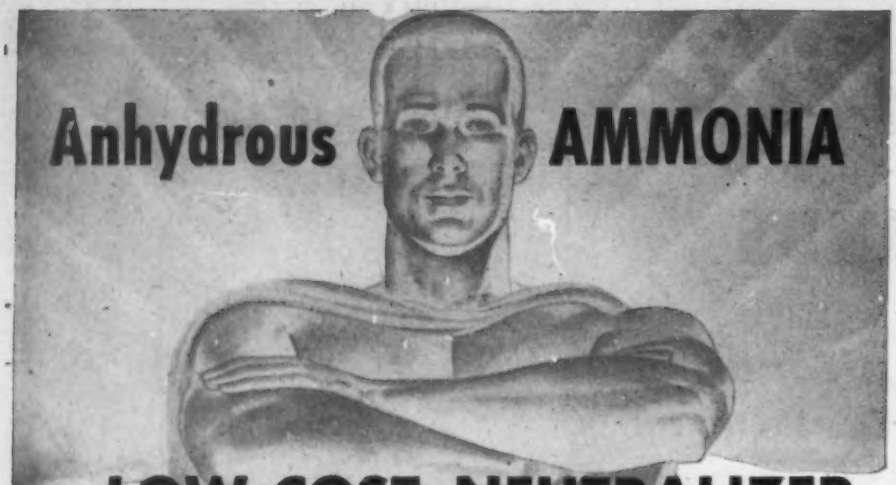

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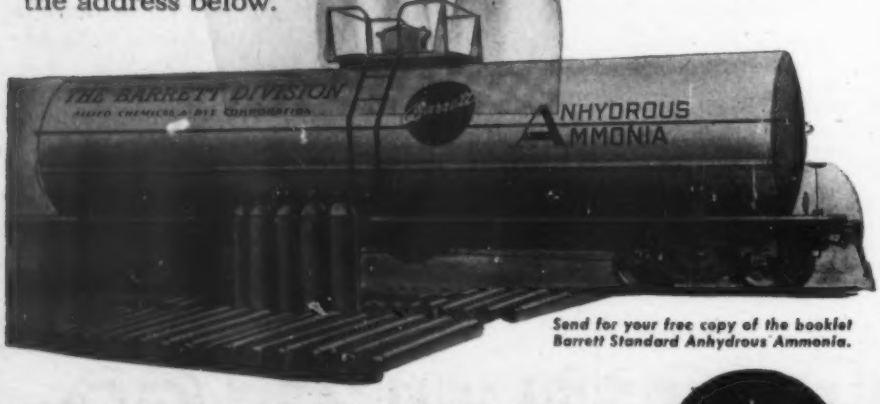

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covered from the effluent of the reaction zone.

U.S.P. 2,408,018. Isomerization Process. O. Gerbes to Standard Oil Development Company.

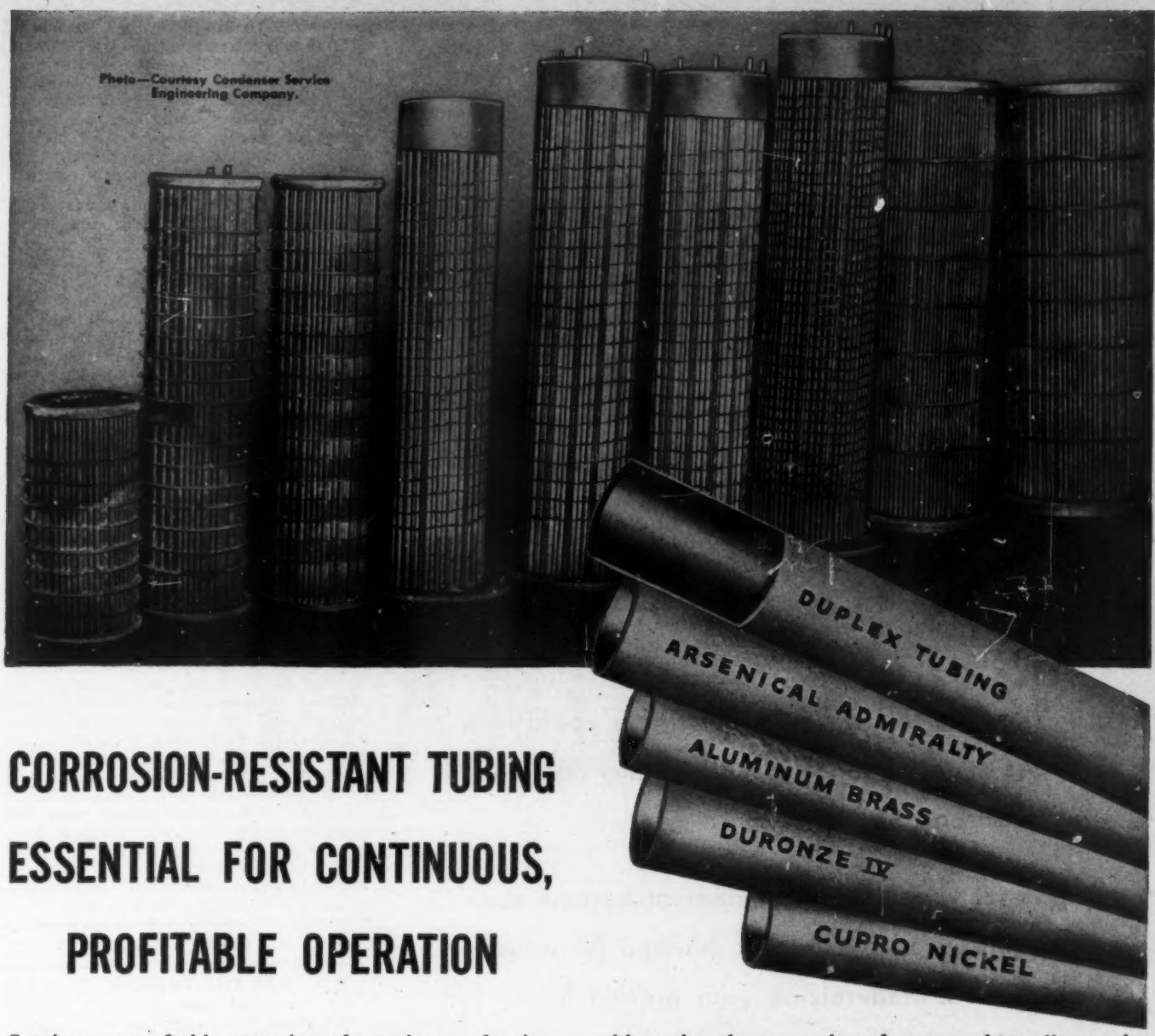
A normal paraffin of at least 4 C atoms in admixture with promotional amounts of hydrogen halide is continuously contacted under isomerizing conditions with a catalyst comprising anhydrous aluminum halide adsorbed on a porous support. Hydrogen halide in the feed mixture is replaced at intervals, as the catalyst activity decreases, with anhydrous aluminum halide without altering the operating conditions. During this period hydrogen halide is introduced to the catalyst bed at a point where the aluminum halide vapors are in equilibrium with aluminum halide adsorbed on the porous support. The quantity of aluminum halide vapors replacing the hydrogen halide in the feed shall not exceed 5 percent by weight of the porous support.

U.S.P. 2,408,186. Catalytic Conversion of Hydrocarbons. H. V. Atwell and H. H. Gross to The Texas Company.

In order to continuously isomerize or otherwise convert hydrocarbons with a liquid Friedel-Crafts metal halide-hydrocarbon complex catalyst in the presence of a hydrogen halide promoter, a stream of feed hydrocarbon is introduced into the lower portion of a tower and a stream of the complex catalyst into the upper portion thereof. The hydrocarbons are moving upwardly through the tower in continuous liquid phase and in direct contact with the downwardly flowing catalyst in dispersed liquid phase. A stream containing converted hydrocarbons is continuously discharged from the upper portion of the tower. A stream of used complex catalyst of relatively low metal halide concentration is continuously discharged from the bottom portion of the tower. The discharged complex is recycled to the upper portion of the tower, and metal halide is introduced to the tower at an intervening point between and removed from the points of converted hydrocarbon and used catalyst discharge. The rate of the metal halide introduction is regulated so that its concentration in the complex catalyst in said intervening portion is substantially greater than in the terminal portions of the tower. The tower may be packed with inert contact material. A conversion temperature of 0-350° F. can be employed.

U.S.P. 2,408,548. Isomerization of Normally Liquid Hydrocarbons. H. S. Bloch to Universal Oil Products Company.

A charge stock of saturated hydrocarbons mixed with a recycling stock formed as indicated hereinafter is passed at isomerization temperature through a Friedel-Crafts catalyst to effect substantial isomerization of the charge stock. The products are separated into portions of like composition. One of these portions is withdrawn from the process, while another portion is mixed with the charge stock. The amount of the charge stock in the resultant combined feed is substantially equivalent to the withdrawn portion of the products obtained. The amount of the other component in the combined feed is regulated to provide in the reaction zone a linear velocity for the combined feed of at least 20 cm. per hour, a residence time not in excess of 15 hours and a



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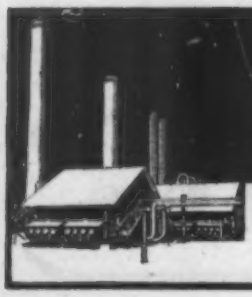

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space velocity not below 0.4 measured as volumes of combined feed per volume of catalyst per hour. Isomerization may be effected in the presence of hydrogen. The process makes possible an increased flexibility of the isomerizing operation. Increased linear velocities appear to effect a scouring action whereby the catalyst surfaces are constantly cleaned.

U.S.P. 2,408,752. Preparation of Branched-Chain Hydrocarbons. R. E. Burk to The Standard Oil Company (Ohio).

Hydrocarbons with 5-8 C atoms, closely fractionated to contain primarily normal to slightly branched-chain paraffinic hydrocarbons, are isomerized with a halide catalyst, such as $AlCl_3$ promoted by HCl, at a temperature below atmospheric temperature. The slightly more branched isomers thus formed are separated and subjected to further isomerization under corresponding conditions to form more highly branched isomers.

U.S.P. 2,408,941. Production of Isoparaffins. J. M. Mavity and W. E. Moss to Universal Oil Products Company.

At least a portion of the paraffin to be isomerized is passed through a bulk supply of aluminum halide disposed in a catalyst supply zone which is maintained under conditions suitable for dissolving a portion of the aluminum halide in the paraffin but not suitable for effecting isomerization. The hydrocarbon effluent containing aluminum halide in dissolved form only is passed to a zone maintained at isomerization conditions. An aluminum halide-hydrocarbon complex is withdrawn from the lower portion of the catalyst supply zone and supplied at least in part to the isomerization zone. Normal pentane can, for example, be isomerized by this process. A temperature of 120-210° F. is maintained in the catalyst-supply zone.

ALKYLATION

U.S.P. 2,407,311. Chemical Process. C. S. Lynch and H. G. Codet to Standard Oil Development Company.

Ethylene is continuously alkylated with an isoparaffin, such as isobutane, by forcing a mixture of these hydrocarbons through a catalyst-charging zone containing $AlCl_3$, where a portion of the $AlCl_3$ is absorbed in the mixture which is then passed into a reaction zone. The mixture remains in the reaction zone until a catalytically active $AlCl_3$-hydrocarbon complex is formed. Elevated temperatures and pressures are then maintained in the reaction zone. A product containing a C_8 fraction of high octane number is withdrawn from the reaction zone. Fresh $AlCl_3$ is added from time to time to the charging zone.

U.S.P. 2,407,390. Chemical Process. C. H. Watkins to Standard Oil Development Company.

Propylene is alkylated with isobutane by contacting propylene and isobutane with $AlCl_3$ for a time sufficient to form a liquid $AlCl_3$—hydrocarbon complex and then contacting propylene with an excess of isobutane in the presence of this complex catalyst. A promoter, such as HCl or an alkyl halide may be added.

U.S.P. 2,407,584 and 2,407,585. Alkylation Process. W. A. Stover to Socony-Vacuum Oil Company.

A paraffinic hydrocarbon is alkylated with an olefinic hydrocarbon in the pres-

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ence of carbon dioxide as the catalyst. The concentration of the olefinic hydrocarbon is controlled so that alkylation is the principal reaction. Triptane and neohexane are, for example, produced from isobutane and propylene, and from isobutane and ethylene, respectively; or a high-octane motor fuel is obtained by reacting a light isoparaffin with a light olefin, generally. A temperature of 650-825° F. and pressures of at least 500 psi are employed. The amount of CO_2 used may vary between 3 percent and 20 percent based on the total volume of the charge.

According to U.S.P. 2,407,585 a mixture of CO_2 and water is used as the catalyst in the alkylating process. The water and the CO_2 may each be used in amounts varying between 3 percent and 50 percent by weight based on the hydrocarbon charge.

U.S.P. 2,408,167. Catalytic Alkylation Process. H. J. Hepp to Phillips Petroleum Company.

A mixture comprising an olefin and a molar excess of an alkylatable aromatic compound, such as benzene, is passed together with not more HCl than 1 percent by weight of the reactants to contact with a solid catalyst under alkylating conditions. The catalyst comprises silica and a minor amount of an oxide of a metal from groups III B or IV A of the periodic system. It is prepared by reacting an alkali silicate with an excess of a mineral acid to form a silicic acid gel which is washed with water and only partially dried to form a hydrous acidic silica gel. This gel is contacted with an aqueous solution of a hydrolyzable salt of one of said metals, such as an aluminum salt. A hydrous oxide of the metal is adsorbed. The material is then washed and dried to form the granular catalyst.

U.S.P. 2,408,329. Alkylation Process. J. R. Meadow to Socony-Vacuum Oil Company.

An excess of paraffinic hydrocarbon with at least 3 C atoms is contacted with an olefin under alkylating conditions in the presence of a HF catalyst and of Cl, Br, or I. Isobutane can, for example, be alkylated with isobutylene by this process to form isooctane. The quality and quantity of the produced alkylate is improved by the addition of elemental halogens to the HF catalyst. The amounts of these additives may vary between 5 percent and 50 percent based on the amount of HF employed.

U.S.P. 2,408,753. Treatment of Hydrocarbons. R. E. Burk to The Standard Oil Company (Ohio).

Hydrocarbons are heated to a relatively high temperature for a short time. The reaction product is separated into C_3 and lighter hydrocarbons containing ethylene and propylene, an aliphatic fraction of C_4 or C_5 hydrocarbons or a mixture of them comprising normal paraffin, and a C_6 and heavier fraction containing aromatics. The fraction containing ethylene and propylene and the aromatic fraction are introduced into an alkylation zone where the propylene is reacted with at least a part of the aromatics. At least part of the normal paraffin hydrocarbon in the aliphatic fraction is isomerized. Unreacted ethylene from the first alkylation zone is used for the alkylation of this isomerized hydrocarbon. The unreacted ethylene can, however, also be used for alkylating the aromatics while using the propylene for alkylating the isomerized aliphatics.

U.S.P. 2,408,798. Alkylation of Mixed Olefins. R. N. Meinert to Standard Oil Development Company.

An isoparaffin, such as isobutane, is alkylated with a mixture of olefins, e.g., a mixture of ethylene and at least 1 olefin with 3-5 C atoms, by contacting the mixed olefins with a mixture of isoparaffin and an $AlCl_3$-hydrocarbon complex catalyst. This catalyst is prepared by agitating a suspension of $AlCl_3$ in an isoparaffin while adding an olefin in small increments until a dark reddish brown mobile liquid complex is formed. Conditions of temperature and pressure maintained during alkylation are the optimum conditions for that component of the olefin mixture which is the most difficult to alkylate. Ethylene may be employed as the olefin used in the preparation of the catalyst.

U.S.P. 2,408,933. Hydrogen Fluoride Alkylation Process. J. A. Iverson to Universal Oil Products Company.

Isoparaffins are alkylated with olefins in the presence of a HF catalyst. A stream of used HF catalyst contaminated with accumulated heavy organic material and water is separated from the alkylating zone and heated to a temperature sufficient to decompose a substantial portion of the organic fluorides contained therein. The heated catalyst is introduced into a flash vaporization zone to effect controlled partial vaporization of the catalyst. The purified vapors and water vapors are removed overhead and unvaporized heavy organic material is withdrawn from the bottom of this zone. Preheated vapors of a relatively-low-boiling hydrocarbon are separately introduced into the bottom of this zone to strip and separate HF from said organic material.

POLYMERIZATION AND CONVERSION

U.S.P. 2,407,214. Production of an Aviation or Motor Fuel or an Aviation or Motor Fuel Constituent. S. F. Birch, F. A. Fidler and L. S. Thornes to Anglo-Iranian Oil Company, Ltd.

Cyclopentane is produced from the benzol forerunnings of a coal-tar distillate by subjecting these forerunnings to polymerization and producing a concentrate in the boiling range of 75-175° C. The concentrate is distilled and an overhead consisting of the light ends boiling at about 78-80° C. and comprising benzene together with some unsaturated and sulfur compounds is separated. The bottoms fraction contains dicyclopentadiene and is subjected to depolymerization to form cyclopentadiene. The latter is directly hydrogenated in the presence of a temperature moderating and reaction stabilizing diluent to yield cyclopentane. The depolymerization is carried out in a column packed with iron or steel in a divided state, such as small pieces or fibre, to obtain a sulfur-free cyclopentadiene as overhead at a column head temperature of 40-42° C. A molybdenum oxide-alumina catalyst is used in the hydrogenation operation at a pressure of about 200 psi and a temperature of about 400° C.

U.S.P. 2,407,371. Conversion of Hydrocarbon Oils. C. E. Jahnig to Standard Oil Development Company.

Hydrocarbon oil is contacted, preferably in vapor form, with a finely-divided catalyst material for a time sufficient to obtain substantial conversion. Catalyst material is continuously removed from the conversion zone and at least in part heated by direct contact with a heating gas to a temperature materially above that maintained in the conversion zone. A portion of the heated catalyst is mixed with the non-heated oil to be converted and the mixture obtained is passed to the conversion zone. The amount of catalyst circulating through the heating and converting zones is controlled to maintain the conversion zone at the desired temperature. The catalyst is regenerated. The process is useful in cracking hydrocarbons and in reforming naphtha.

U.S.P. 2,407,701. Manufacture of Halogenated Hydrocarbons. D. G. Jones and M. Phillipson to I.C.I. Ltd.

A gaseous mixture of a hydrogen halide and acetylene is passed over a supported $HgCl_2$ catalyst at reaction temperature to form vinyl chloride. The flow of reaction mixture is interrupted when the activity of the catalyst has substantially decreased. Catalyst activity is restored by passing chlorine over the catalyst at elevated temperature. Adsorbed chlorine may be removed from the regenerated catalyst by hydrogen halide at an elevated temperature.

U.S.P. 2,407,873. Polymerization of Olefins. B. L. Evering, E. L. d'Ouville and D. R. Carmody to Standard Oil Company (Indiana).

Aluminum chloride is contacted with an aromatic-free normally liquid saturated hydrocarbon fraction to effect isomerization and to form an $AlCl_3$-hydrocarbon complex which on hydrolysis would yield a hydrocarbon oil of lubricating-oil viscosity. The complex contains 1-5 mols of $AlCl_3$ per double bond of the oil which would result from hydrolysis. The $AlCl_3$ complex is separated from isomerized hydrocarbons. Normally gaseous olefins are then treated in the presence of this $AlCl_3$ complex under polymerization conditions.

U.S.P. 2,408,007. Method for Recovery of Low-Temperature Polymerization Products. R. M. Thomas and D. C. Field to Jasco, Inc.

A mixture containing 70-99 parts of isobutylene, and 30-1 parts of a conjugated diolefin of 4-8 C atoms, such as butadiene, isoprene, or dimethyl butadiene, is polymerized at a temperature of from —50° to —150° C. in the presence of a catalyst consisting of a solution of $AlCl_3$ in an inert solvent which is liquid at the reaction temperature, such as ethyl chloride or carbon disulfide. A solid polymer product containing occluded catalyst is formed, preferably as a slurry of separate particles dispersed in the reaction mixture. The product obtained is contacted at about the same temperature with a volatile hydrocarbon solvent. Polymer solution is washed with water to remove aluminum compounds present. An alcoholic catalyst quenching agent may be added to the hydrocarbon solvent to destroy the activity of catalyst occluded in the polymer. Naphtha can be used as the hydrocarbon solvent and isopropyl alcohol as the catalyst quenching agent.

U.S.P. 2,408,010. Purification of Ethylene. E. F. Wadley and J. T. Horeczy to Standard Oil Development Company.

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lene is scrubbed with a boron fluoride-sulfuric acid catalyst mixture under conditions suitable for the selective polymerization of propylene. A temperature of 60-125° F. and a pressure not substantially in excess of 150 psi are employed. The catalyst mixture contains 5-50 percent by weight of boron fluoride, and the sulfuric acid which forms the remainder of the mixture may range in strength from 40 to 85 percent.

U.S.P. 2,408,294. Catalytic Conversion of Hydrocarbons. S. C. Carney to Phillips Petroleum Company.

Hydrocarbons are converted by contacting them with $AlCl_3$ under suitable conditions. The vaporous effluent which contains hydrocarbon vapors and $AlCl_3$ vapors is contacted with liquid $SbCl_5$. $AlCl_3$ is removed from the hydrocarbon vapors by dissolving it in the liquid $SbCl_5$. The aluminum chloride is returned to the reaction zone after separation from liquid $SbCl_5$. The use of catalyst and hydrocarbons in vapor phase permits perfect contact, while an easy separation of the catalyst vapors from the hydrocarbon vapors is made possible by the use of liquid $SbCl_5$.

U.S.P. 2,408,725. Hydrocarbon Conversion. A. Belchetz to The M. W. Kellogg Company.

Olefin hydrocarbons are absorbed in an acid polymerizing catalyst at temperatures below polymerizing temperatures. The extract obtained is mixed under pressure with hydrocarbon vapors comprising at least a substantial proportion of an isoparaffin boiling above the polymerizing temperature at polymerizing pressure, and the mixture is heated under this pressure to a temperature sufficiently high to polymerize the absorbed olefins in the liquid phase. Regenerated acid catalyst and a mixture comprising the polymers and the isoparaffin are separated from the product obtained. The catalyst is recycled to the absorption step. The hydrocarbon mixture is alkylated.

U.S.P. 2,408,943. Conversion of Hydrocarbons. L. A. Mekler to Universal Oil Products Company.

Finely divided catalyst particles are contacted with hydrocarbons under conversion conditions. The contaminated catalyst is continuously withdrawn and, prior to its regeneration with oxygen-containing gas, passed downwardly through a coking zone in countercurrent contact with hot spent regenerating gas. The amount and temperature of this gas and the time of contact has to be sufficient to reduce to low-volatile coke and vapors the occluded and absorbed liquid hydrocarbons contained in the contaminated catalyst. The treated catalyst is removed from the bottom of the coking zone while the regenerating gas is removed from the upper part of this zone and freed from entrained catalyst. The latter is combined with the catalyst withdrawn from the bottom of the coking zone and regenerated together with it.

HYDROGENATION DEHYDROGENATION AROMATIZATION

U.S.P. Re. 22,800 (Original 2,370,797). Method for the Catalytic Dehydrogenation of Hydrocarbons. K. K. Kearby to Standard Oil Development Company.

Monoolefins and aralkyls with at least 2 C atoms in the alkyl group are dehydrogenated by contacting them under suitable conditions with a dehydrogenation catalyst comprising a major proportion of ZnO, a minor proportion of iron oxide, manganese oxide, chromium oxide, cobalt oxide, or nickel oxide, and a small amount of K_2O as a promoter. The hydrocarbons to be treated can be diluted by steam, and a hydrogenation temperature of 1000-1600° F. may be employed.

U.S.P. 2,407,373. Dehydrogenation of Hydrocarbons. K. K. Kearby to Standard Oil Development Company.

Butadiene is produced by contacting a mixture of butene and steam with a catalyst consisting of a major portion of CuO, a minor portion of Cr_2O_3, Fe_2O_3, or MnO_2, and a compound of K, such as K_2O as a promoter. The catalyst is preferably held at a temperature of 1100-1300° F.

U.S.P. 2,408,131. Process for Dehydrogenating Hydrocarbons. A. Vorhies, Jr., to Standard Oil Development Company.

Hydrocarbons with 2-5 C atoms, such as isobutane, are passed at dehydrogenating temperatures and pressures over a catalyst which consists of a major proportion of Al_2O_3 and minor substantially equal proportions of Cr_2O_3 and Ni_2O_3, such as a mixture of about 96 percent Al_2O_3, 2 percent Ni_2O_3 and

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When you employ STOKES to paint or coat your equipment . . . whether it be a single tank, or a complete refinery layout, you are guaranteed a first-class job.

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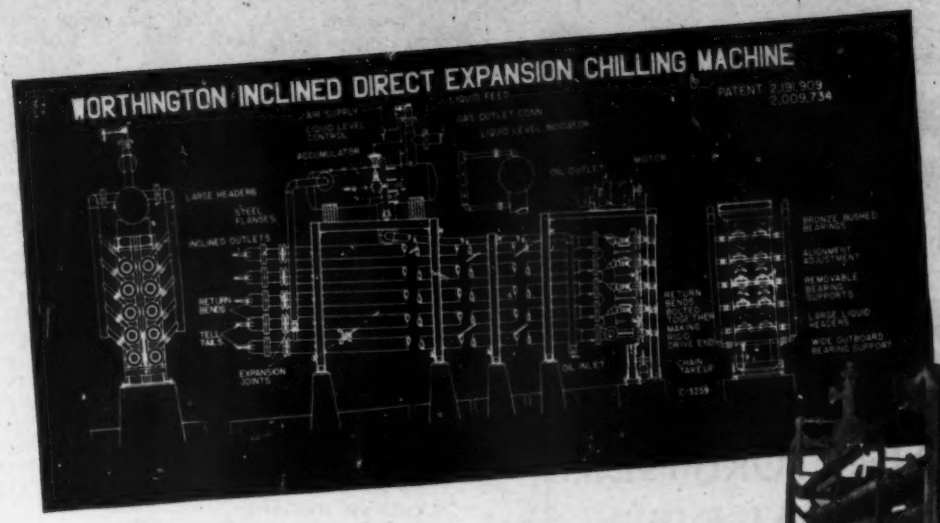


Here's The Right "SLANT" On Chilling Machines

And that's far more than just a figure of speech, because Worthington Double-Pipe Chilling Machines *are* slanted! They're set in an *inclined* position — an important Worthington exclusive — so that the refrigerant-vapor outlet is higher than the refrigerant-liquid inlet.

MAXIMUM HEAT-TRANSFER ASSURED

Liquid refrigerant enters the bottom of each chilling section, and any unused surplus is swept back to the accumulator by the upward flow of vapor. And *only* liquid refrigerant reaches the chilling sections (at saturated temperature) because "flash" gas, formed in the accumulator as the refrigerant evaporates, returns directly to the refrigerating unit. In addition, spring-loaded scrapers, rotating inside the inner pipes, remove all heat-retarding accumulations of crystals as soon as they form.

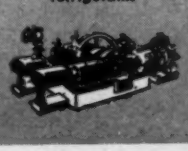
Improved design features like these greatly increase overall efficiency by assuring maximum heat-transfer at all times . . . And remember: *only Worthington Chilling Machines have them all!*

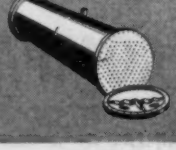
CONCERNING EXCHANGERS

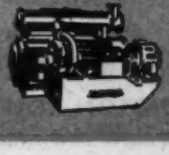
Although they are set level and involve a different method of applying the chilling medium, Worthington Double-Pipe Exchangers have the same general construction as Worthington Chilling Machines. Essential features common to both are: special safety scraper-drive with shearing protection for each section; easily removable drive shaft with pressure-lubricated bearings; external ball-type thrust bearings; improved chain-and-sprocket-type main drive with adjustable outboard bearings . . . Bulletin C-1100-B-15 contains full information on these outstanding Chillers and Exchangers, and further proof that *there's more worth in Worthington*. For your copy, write today to *Worthington Pump and Machinery Corporation, Harrison, New Jersey.* A6.23

WORTHINGTON

FIVE MORE REASONS WHY WORTHINGTON LEADS IN INDUSTRIAL REFRIGERATION


Horizontal compressors for all types of refrigerants


Shell and tube refrigerating equipment


Centrifugal compressors

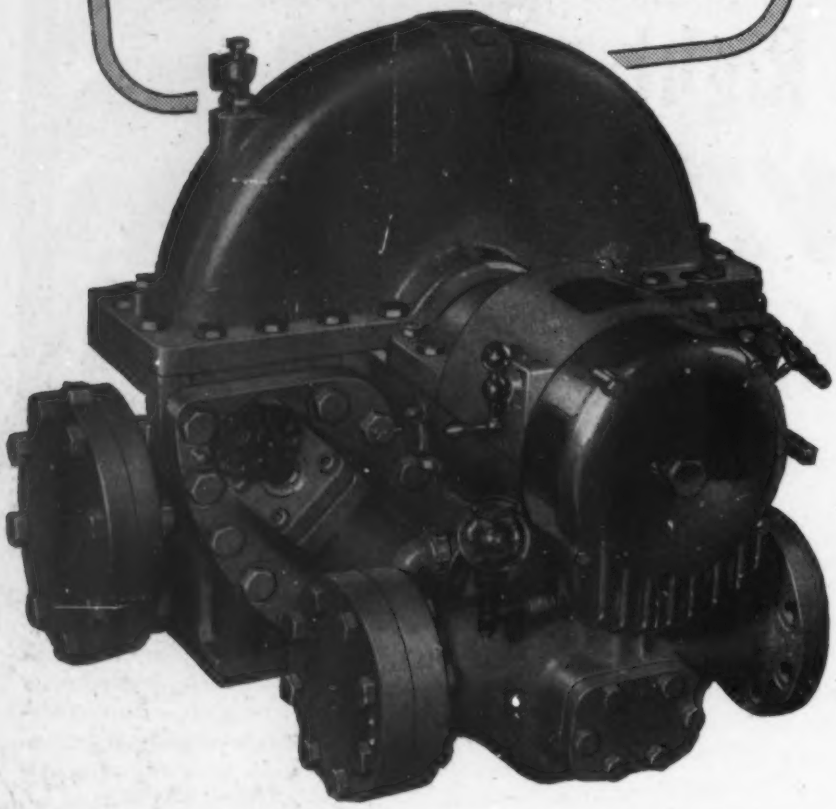
Absorption refrigerating machines

Chilling machines and exchangers

MURRAY

TYPE S

SINGLE STAGE TURBINES
FOR MECHANICAL DRIVE



Murray Type S single stage turbines for mechanical drive have horizontally split casing with steam and exhaust connections in lower half. Two-row impulse type stainless steel blading. Completely enclosed constant speed governor and emergency overspeed governor. Carbon ring glands. The unit is compact with the ruggedness expected on this type drive. Suitable for driving centrifugal pumps, fans, blowers, and small generators.

Write today for Murray Bulletin 121 — it illustrates and describes in detail Murray Type S Turbines.

Murray also produces:

Turbine Generators up to 3,000 KW rating.
Vertical Steam Turbines, both direct connected and geared.
High speed reduction gears.
Steam Boilers.

MURRAY IRON WORKS COMPANY

BURLINGTON, IOWA

BUILDERS OF STEAM POWER EQUIPMENT FOR THREE QUARTERS OF A CENTURY

2 percent Cr_2O_3 which has been preheated to 1800-2000° F.

U.S.P. 2,408,139. Dehydrogenation Process. C. L. Gutzeit to Shell Development Company.

Mono-olefins with at least 4 non-quaternary C atoms in a straight chain, such as n-butylene, are continuously dehydrogenated to form diolefins, such as butadiene, by contacting them in the presence of at least 2 mols of steam per mol of mono-olefin at a temperature above 580° C. and at a gaseous hourly space velocity between 300 and 3000 with a catalyst consisting of an essentially homogeneous mixture of a major proportion of iron oxide, a smaller proportion of bismuth oxide and a minor amount of potassium oxide. The bismuth oxide may be present in an amount of 1-40 percent and the potassium oxide in an amount of 0.2-5 percent of the catalyst mixture.

U.S.P. 2,408,724. Toluene Process. J. C. Bailie and R. V. Shankland to Standard Oil Company (Indiana).

Toluene in high concentration is obtained from petroleum naphtha by contacting naphtha having an average boiling point within about 50° F. of the boiling point of toluene at 850-1100° F. with a catalyst substantially free of alkali metals and consisting essentially of alumina gel promoted with 5-10 percent of molybdenum oxide. About 1-5 mols of hydrogen per mol of naphtha are charged to the reaction. The catalyst is prepared by dissolving amalgamated metallic Al in a weak acid, such as dilute acetic or formic acid, gelling the thus formed sol, drying and igniting the resulting alumina gel, impregnating the ignited gel with a solution of a soluble molybdenum compound and re-igniting the catalyst.

HEAVY OILS AND WAXES

U.S.P. 2,407,954. Lubricating Composition. M. R. Fenske and G. H. Cummings to Rohm & Haas Company.

The lubricant comprises a lubricating oil and an oil-soluble, polymerized ester of the general formula

$$CH_2=\underset{\underset{X}{|}}{C}-\overset{\overset{O}{\|}}{C}OR$$

wherein X is hydrogen or the methyl group and R is a saturated hydrocarbon group of at least 5 C atoms. The polymerized ester is present in an amount sufficient to improve the lubricating properties of the oil. A hydrocarbon oil-soluble, alcoholic hydroxyl-containing ester of a polyhydric aliphatic alcohol and a long-chain fatty acid is also added in an amount sufficient to reduce the emulsifying tendency of the oil containing the polymerized ester alone. A copolymer of cetyl alpha-methacrylate is an example of the first class of addition compounds and glyceryl monoricinoleate is an example of the second class.

U.S.P. 2,408,090. Lubricating Oils. S. Musher to Musher Foundation, Inc.

Lubricating oil is blended with a relatively small amount of phosphatide and a mononuclear aromatic sulfur-containing compound. These compounds are added in amounts from 0.075 to 0.75 percent to the oil. Lecithin is, for example, used as the phosphatide and thiodiphenylamine or phenylsulfide as the second component. Sludge formation and the tendency of the oil to cause corrosion of metal surfaces is decreased.

NEW EQUIPMENT

. . . MANUFACTURERS' · LITERATURE . . .

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1—Thickness Gauge

Branson Instruments, Inc., Joe's Hill Road, Danbury, Connecticut, has announced development of the "Audigage" Thickness Gauge, Model FMSS-4.

The "Audigage" is a portable, self-contained instrument designed to measure the thickness of many materials, including steel, from one side only. Its application to problems of thickness determination of pipes, storage tanks, pressure vessels, and ship hulls, for example, is non-destructive and provides rapid, accurate and reliable results.

The "Audigage" utilizes a crystal-type gauge head, powered by a frequency-modulated electronic oscillator. When the vibrating crystal is applied to a wall surface, mechanical resonance of the wall thickness can be produced directly below the crystal.

The fundamental frequency at which the wall section will resonate is directly proportional to the velocity of the sound in the material and inversely proportional to thickness. The wall thickness also will resonate at all harmonics of the fundamental frequency. The "Audigage" provides a means whereby audible signals are produced corresponding to harmonic resonance. The frequency difference between any two adjacent audible signals as read on the tuning dial is readily converted into wall thickness on a concentric thickness scale.

The "Audigage" provides other information than thickness alone. The character of the audible indications varies with several factors, such as kind of material, condition of reflecting surface, back-up liquids, process scale, etc. These factors provide useful information, but do not influence the accuracy of the thickness measurement.

This new product can best be characterized by its specifications: Acoustic indications, high sensitivity, compactness, light weight, high accuracy, direct reading, battery-operated. It can be applied to steel, aluminum, brass, copper, glass, and other materials, and covers a range of from ⅛-inch to 12 inches.

A descriptive folder gives detailed specifications and application possibilities.

CHECK THE CARD AT PAGE 248

2—Weigh Beam for Range Change

Republic Flow Meters Company, 2240 Diversey Parkway, Chicago 47, announces that Republic pneumatic pressure and differential pressure transmitters now can be furnished with an adjustable weighbeam—a new development which makes possible a 15-to-1 range change without change of parts. The only readjustment necessary is rebalancing for zero.

This feature is provided by replacing the standard weighbeam by a double weighbeam having an adjustable pivot between the two halves. The range of

"Audigage" Thickness Gauge

the transmitter is changed by merely sliding the adjustable pivot along a calibrated scale to the desired setting. For example: a differential transmitter having a minimum range of from 0 to 1.0 inch of water can be changed to any range up to 0 to 15.0 inches; similarly a transmitter with a minimum range of 0 to 8.0 inches can be changed to any range up to 0 to 120.0 inches.

The flexibility of application provided by this new development is of paramount importance on those installations where operating conditions are highly variable or on new installations where flow or pressure conditions are unknown, it was explained.

CHECK THE CARD AT PAGE 248

3—Pumps

The Duriron Company, Dayton 1, Ohio, has available an illustrated Bulletin No. 813, "How to Pack Your Durco-pump." Written specifically to apply to the company's line of corrosion-resisting pumps, the data presented also is applicable to all chemical or corrosion-resisting centrifugal pumps.

CHECK THE CARD AT PAGE 248

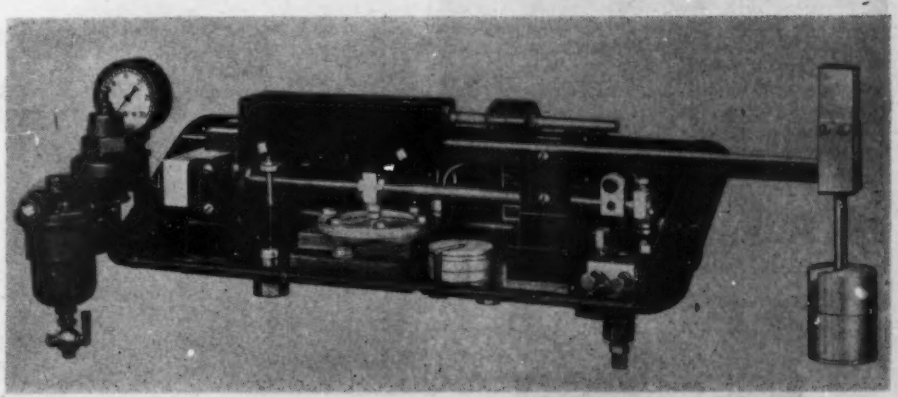
4—Tachometer

Metron Instrument Company, 432 Lincoln Street, Denver 9, Colorado, has announced availability of a new switchboard tachometer, Type 40E.

This instrument has permanently mounted tachometer heads at five different machines. These tachometer heads are wired to the central indicating unit by ordinary BX cable or conduit. There is a rotary selector switch on the indicating unit for selecting the machine whose speed is to be measured. These machines may be remote from the location of the indicating unit, in fact, these machines may even be in different buildings.

The scale shows three separate speed ranges. These may be any range between 1 rpm full scale and 50,000 rpm full

Metron Type 40E Tachometer



Republic Weigh Beam

PRINCO LOW TEMPERATURE THERMOMETERS

PRINCO "PRINTANE" THERMOMETERS

Check these advantages of the new PRINCO #164 "Printane" Thermometer. Maximum range. Accurate over full range of +30° C. to —200° C. *Greater stability.* Improved fluid will not separate at +60° C., yet can remain at —200° C. for 24 hours or more without loss of accuracy. *Higher visibility.* Non-precipitating, *dyed* fluid is used. *Better legibility.* The PRINCO "Printane" is easier to read. New fluid permits more uniformly spaced scale. Range +30 to —200° C. in 1°. 400 mm. long.

PRINCO "MERCUTHAL" THERMOMETER

The PRINCO #76-00 "Mercuthal" Thermometer brings advantages of mercury-in-glass laboratory thermometer to temperatures as low as —60. Successful operation made possible by Princo "Mercuthal" (improved mercury-thallium alloy). Affords greater accuracy, stability, and sensitivity than fluid-filled instruments formerly required for this range. Range +2 to —60° C. in 0.2°. 400 mm. long.

PRINCO "TOLUOL" THERMOMETER

For medium low ranges (—95° minimum) specify PRINCO #163 Toluol Thermometers: Made according to Bureau of Standards requirements. Brilliant, easy-reading, red fluid. Range +30 to —95° C. in 1°, 350 mm. long.

LOW RANGE "SPECIFICATION" THERMOMETERS—Consult PRINCO if you use "Specification" Thermometers. PRINCO thermometers are made in strict accordance with the latest specifications of the various technical societies, National Bureau of Standards, Federal Specifications Board, and private industry. Low-range items include "Rubber Reserve Styrene Test" and "A.S.T.M. Viscosity Specification" Thermometers. Write for latest information and prices.

PRECISION THERMOMETER & INSTRUMENT COMPANY

PRINCO

PRECISION INSTRUMENTS FOR INDUSTRY

1417 Brandywine St., Philadelphia 30, Pa.

scale. A rotary selector switch is mounted on the panel of the indicating unit for selecting the proper speed range.

Instruments are available in box-type switchboard units for mounting on the front of a switchboard or wall, or in the flush switchboard type.

This tachometer does not employ either a generator or magneto. Operating power is obtained from the commercial 115-volt AC power supply. Accuracy and calibration are not affected by changes in line voltage between 105 and 125 volts because of a voltage stabilizer built right into the indicating unit.

The tachometer head is a simple reversing switch positively actuated in both directions by means of a cam mechanism. The tachometer shaft is the only rotating part. The reversing switch alternately charges and discharges a condenser through a milliammeter causing the milliammeter to deflect in direct proportion to the speed of rotation of the tachometer shaft. This tachometer contains no vacuum tubes or other limited-life components. Most models operate at the extremely low torque of only 1/30 ounce-inch. These tachometers can not be damaged by overspeeding or selecting any speed range while all tachometer heads are running.

The accuracy of this tachometer is 1 per cent.

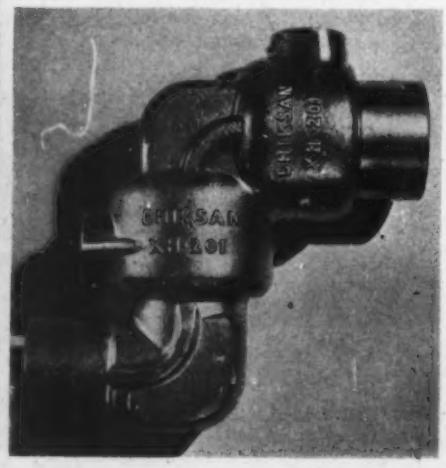
CHECK THE CARD AT PAGE 248

5—High-Pressure Swivel Joint

Chiksan Company, Brea, California, has announced the new Chiksan XH (extra high pressure) swivel joint, built for working pressures of 12,000 psi, with low torque and positive packing seal-off.

Rotating members are steel forgings, machined to close tolerances and with flame-hardened ball races. Full 360° rotation with low torque takes place on two rows of hardened steel balls which also serve to hold the rotating members together under pre-regulated pressure. The packing element is specially designed for high-pressure service and is self-adjusting.

Type XH employs no bolted flanges, locking rings or stuffing boxes. There is nothing to tighten or adjust. High-pressure lubricating fittings provide for positive lubrication of the bearings. Inside diameter is unobstructed, permitting full flow of liquids, gases and vapors with minimum friction loss and turbulence. End connections are of the high-pressure, tapered thread type. This joint is recommended for all high-pressure services to 12,000 psi, where maximum flexibility, easy turning, minimum maintenance, long life and maximum safety are essential.



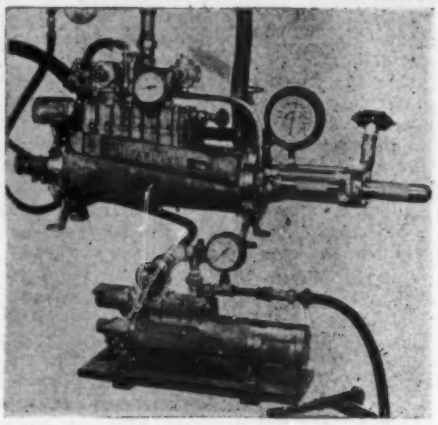
Chiksan XH High-Pressure Swivel Joint

CHECK THE CARD AT PAGE 248

6—Hydrostatic Test Pressure Pumps

McFarland Manufacturing Corporation, 1630 Roberts Street, Houston, Texas, has announced two hydrostatic testing units and pressure pumps that operate on water, air, gas or steam, and discharge liquids or gases at pressures directly proportional to operating pressures.

Units are double-acting reciprocating pumps, available with or without booster attachments. Main castings and most parts are aluminum bronze.



McFarland Pressure Pumps

Discharge-inlet pressure ratios up to 200-1 are obtained with the 6-5¼ unit: discharge pressure of 12,000 psi when operating on city water pressure of 60 psi. Other ratios are obtained by changing the cylinder and piston in the booster. Without booster, the 6-5¼ unit operates at 4.25 to 1 ratio. The smaller 3-2½ unit operates at ratios from 2 to 1 to 4.5 to 1.

Discharge pressures are confined to the booster; the highest pressure to which the body is subjected is the input operating pressure. Desired pressures are maintained automatically once they are reached.

McFarland units are recommended by the manufacturer for hydrostatic testing of pressure vessels and equipment, or for other purposes where liquids or gases need be discharged under pressure and in low or medium volume.

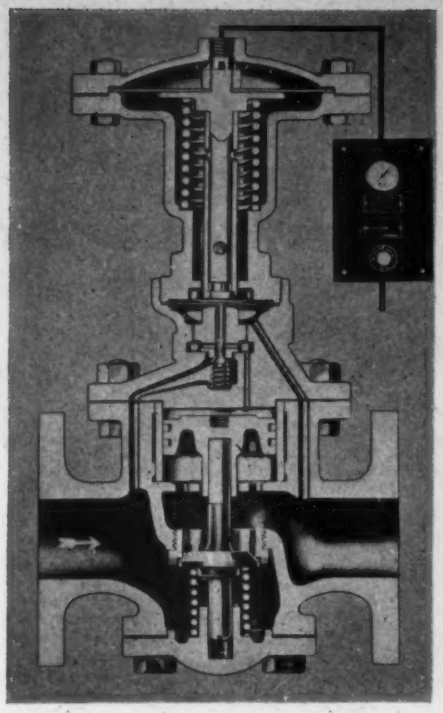
CHECK THE CARD AT PAGE 248

7—Remotely Adjusted Regulating Valve

Leslie Company, Lyndhurst, New Jersey, has announced a new single-seated, internal-pilot, piston-operated reducing valve designed to be remotely adjusted from a conveniently located air-loading panel.

Known as Class LT-3, this reducing valve with the Type ARP air-loading panel is especially adaptable to process piping arrangements, particularly steam-heating systems, that require hazardous or inconvenient readjustments of inaccessibly located valves to meet changing conditions.

The air-loading panel includes a small



Leslie Class LT-3 Reducing Valve, Remotely Adjusted, and Type ARP Control Panel

1/8-inch combination pressure-reducing and relief valve (no continuous leak-off) mounted on a panel containing an adjusting knob and a large, easily read air-pressure gauge.

In operation, the reducing valve is adjusted to the desired pressure setting by air pressure supplied by the air-loading panel. The constant loading force on the upper diaphragm of the reducing valve opens the controlling valve and is balanced by a constant reduced pressure proportional to the loading force, thereby maintaining a constant reduced pressure.

Turning the adjusting knob on the air-loading panel clockwise increases loading pressure and reduced steam pressure, while counter-clockwise turning decreases loading pressure and reduced steam pressure.

Furnished in high-pressure bronze or cast-steel body with flanged or screwed ends, these valves have completely interchangeable replacement parts, stellited seat rings, and hardened stainless-steel 800-Brinell main valves as standard equipment.

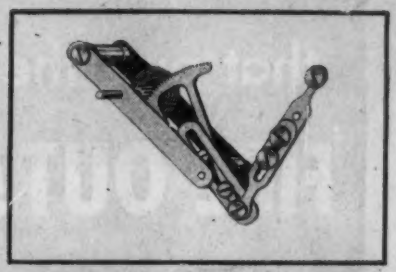
CHECK THE CARD AT PAGE 248

8—Boiler Feedwater Control

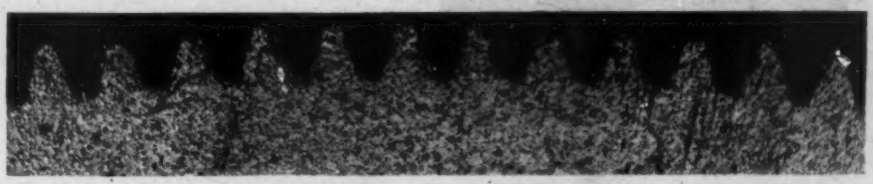
Combustion Controls Corporation, 77 Broadway, Cambridge 42, Massachusetts, has announced the Fireye Boiler Feedwater Control Type 15GK1, an automatic control for maintaining boiler-water level and turning off fuel supply and sounding an alarm at low water level. It contains no moving parts, floats or bellows seals. It is an alternating-current control that combines a probe circuit and transformer to operate a direct-current relay through a rectifier. Closure of the probe circuit alters the magnet field of the transformer so that current is generated in the rectifier-relay circuit energizing the relay.

A three-probe fitting is mounted parallel to the water column and wired to the control. The top and middle probes de-

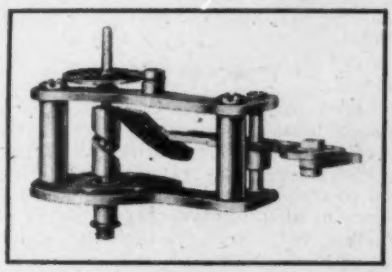
HELICOID GAGES
Remain Accurate Longer
HERE'S WHY:



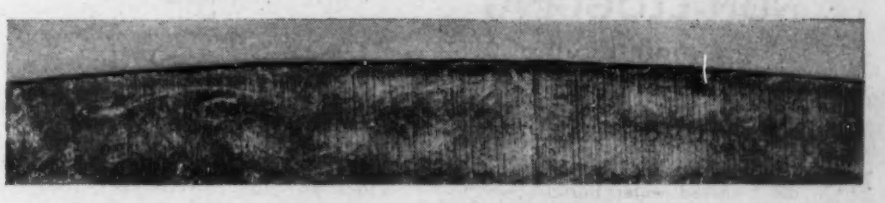
The movement of the ordinary pressure gage operates by means of a toothed segment and a spur gear as shown at right.



Magnified 12 times, the teeth of this new, unused sector are jagged – anything but uniform. Pinion teeth are cut the same way. Friction, wear and consequent inaccuracies are caused by these rough surfaces rubbing together.



Helicoid Gage movement has a polished, graphited Bakelite cam and a polished helicoid roller – instead of sector and pinion.



Cam of Helicoid movement magnified 12 times, shows smooth, polished surface. Helicoid roller surface is also highly polished. Longer wear and smoother operation result from these two polished surfaces in rolling, point contact.

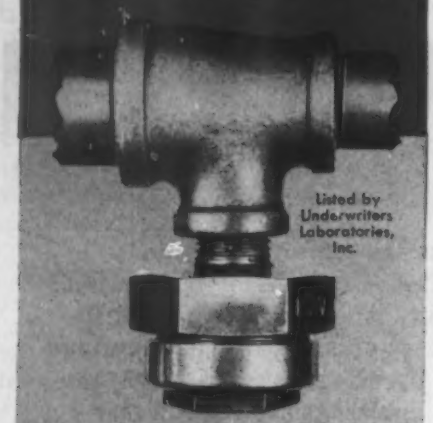
Only Helicoid Gages have the Helicoid movement. That is one of several reasons why Helicoid is a better, longer-lasting pressure gage. Write for our complete catalog.

ACCO

HELICOID GAGE DIVISION
AMERICAN CHAIN & CABLE

TRADE MARK

It's Water on the Fire that puts the FIRE OUT!



Listed by Underwriters Laboratories, Inc.

BLAW-KNOX AQUATOMIC FOG NOZZLES ARE NON-CLOGGING and maintain the spray pattern at reduced pressures

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termine the high and low level at which the feedwater pump is turned off and on to maintain water level. The lowest probe defines the danger point below which water must not fall, in which event fuel is shut off and an alarm sounded.

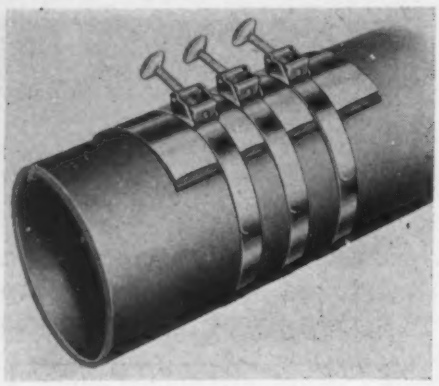
Full details are available by writing.

CHECK THE CARD AT PAGE 248

9—Pipe-Leak Clamp

Marman Products Company, 940 W. Redondo Boulevard, Inglewood, California, is manufacturing an all stainless-steel pipe-leak clamp, tested without leaking at pressures exceeding 240 psi.

The clamp consists of a Hycar pad which is resistant to deterioration by water, gas, oil, etc. An annealed backing plate covers the pad and can be



Marman Pipe-Leak Clamp

formed to the pipe contour. Pad and patch plate are secured with stainless-steel clamps of the continuous band type which have a size range from 9/16-inch up to maximum diameter for clamp. Six sizes fit all pipe diameters from ½ to 12 inches. Sizes over 12-inch are available on special order.

A folder is available.

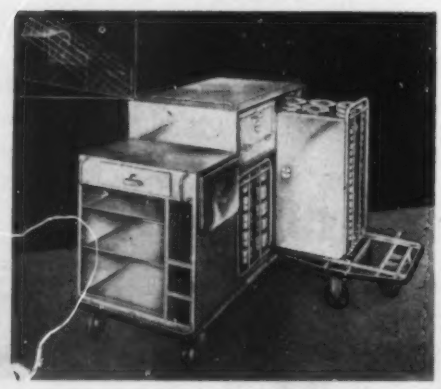
CHECK THE CARD AT PAGE 248

10—Food Service Cart

Mealpack Corporation of America, 152 West 42nd Street, New York 18, is making a new canteen food service cart, "Mealpack Mobile Canteen, Model 83," which provides for compact storage and quick dispensing of individual hot meals for office and plant workers.

Recesses built into the cart receive two handling racks which offer storage for up to 83 containers holding individual meals marked to show pre-ordered menus or for selection.

The canteen is loaded with packed



Mealpack Mobile Canteen, Model 83

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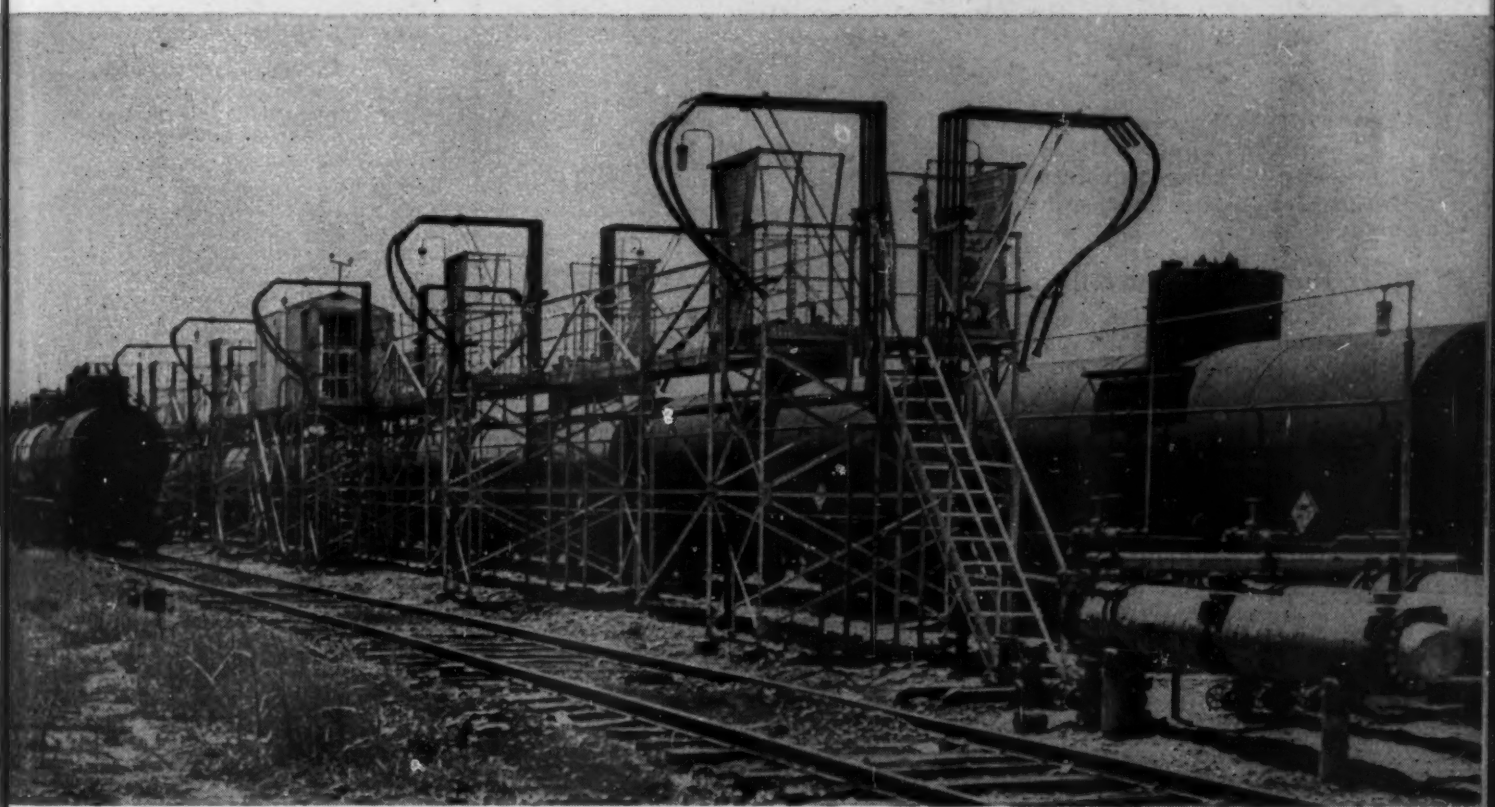

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containers by a loading system. Handling racks are loaded with filled containers at the kitchen and trundled on a dolly to the canteen.

Rubber-tired casters make operation quiet and easy and compactness permits movement in crowded quarters.

CHECK THE CARD AT PAGE 248

11—Silicon Gaskets

General Electric Company, Chemical Department, Pittsfield, Massachusetts, has announced new applications for G-E silicone rubber as gaskets in high-temperature equipment such as diesel engines, gas turbines and air compressors.

Engineers stated that the silicone gaskets are being incorporated between the supercharged and diesel engine block in the new supercharged diesel electric locomotive because of the positive gasketing action they provide at 300° F. and 15 pounds air pressure.

Advantages of the silicone rubber for these applications include its ability to remain soft and resilient at high operating temperatures, its low permanent set and its nonadherence to metals. The excellent heat resistance results in fewer replacements and less time lost due to repairs. Silicone rubber is also a good electrical insulator and has good arc resistance and non-tracking characteristics.

G-E silicone rubber, it was said, remains practically unaffected when subjected to temperatures ranging from minus 55° F. to 520° F. It combines excellent moisture and chemical resistance and, because it does not contain sulphur in any form, metal inserts are not corroded.

G-E silicone rubber is available in extruded shapes, molded parts, sheet stock and fabricated stocks. Extruded rubber is available in rods, tubes, flat strips or a large variety of desired shapes for which a die may be made. Sheet stock is available in thicknesses from 1/32-inch to 3/4-inch and also may be reinforced with plies of glass and asbestos cloth to give greater strength. Molded parts can be made in any of the conventional types of compression molds and are now being produced in increasingly intricate shapes.

General Electric Company officials stated that reduced costs and a consequent broadening of uses for G-E silicone rubber would be effected when production in a new factory at Waterford, New York, is begun shortly after the first of the year.

CHECK THE CARD AT PAGE 248

12—Flow-Rate Instruments

Fischer & Porter Company, Hatboro, Pennsylvania, has available its Catalog Section 40-A, which includes data on flow-rate instruments for high pressures and temperatures. Recording, controlling, integrating, remote and close-coupled instrument accessories also are shown.

CHECK THE CARD AT PAGE 248

13—Color

E. I. du Pont de Nemours and Company, Finishes Division, Department M-6, Wilmington 98, Delaware, has available "Du Pont Color Conditioning for Industry," a new 32-page booklet in full color. Illustrating and describing research and experience with color to increase production, improve seeing conditions and create better working en-

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SEE PAGE 26

Why PALMETTO Self-Lubricating PACKINGS last longer ...cost less

1 Individual strand of yarn —best obtainable Canadian white asbestos—before impregnation.

2 The saturated yarn—after impregnation with special PALMETTO lubricant.

3 The finished product—the completely Self-Lubricating PALMETTO Braided Packing.

Here you see three stages in the exclusive process which makes PALMETTO Packings "*Self-Lubricating*". In this process *each separate strand* of asbestos or cotton is saturated with a special PALMETTO lubricant—forced into the yarn under heat and pressure! At the same time, each strand is *individually graphited* . . . the graphite flakes act as dams to trap and hold a reservoir of lubricant in the yarn. After this, the impregnated strands are braided, plaited or twisted—round or square—to the size required to form the finished *self-lubricating* packing. The result? A completely and permanently lubricated PALMETTO Packing with these five advantages:

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3. *Reduced wear on machinery parts*—because there is a film of lubricant between the packing and moving rods or shafts at all times.
4. *Easier removal and installation*—because packing stays easy-to-handle and does not disintegrate in service.
5. *Lower maintenance costs*—because packing functions without frequent adjustment or constant attention.

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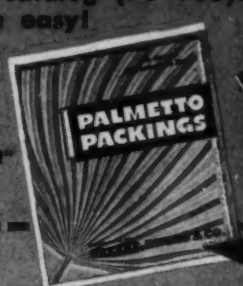

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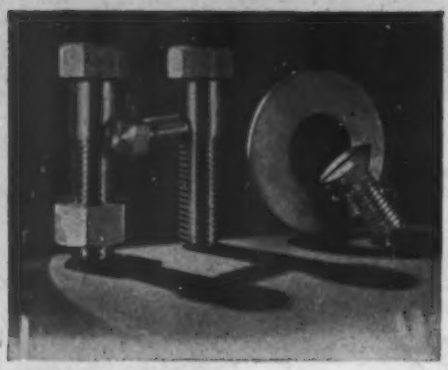

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vironment, the booklet makes clear the principles on which color conditioning is based. "Three-dimensional seeing" treatment of machines is depicted with photographs. The safety color code for industry is outlined.

CHECK THE CARD AT PAGE 248

14—Asbestos-Protected Cables

The Okonite Company, Passaic, New Jersey, has available Bulletin OK-2061, describing the principal types of "Okobestos" heat- and corrosion-resistant wires and cables. This eight-page reference publication describes power cables, apparatus cables, multi-conductor control cables, switchboard wire and appliance wire. Voltage, operating temperatures and work location data are included.

CHECK THE CARD AT PAGE 248

15—Water-Softening Methods

The Permutit Company, 330 West 42nd Street, New York 18, has available a booklet which contains data on basic types of ion-exchange water softeners for industrial and municipal use.

CHECK THE CARD AT PAGE 248

16—Pulsation Dampener

The Fluor Corporation, Ltd., 2500 South Atlantic Boulevard, Los Angeles 22, has issued a new Bulletin PD-1, titled "The Effects and Corrections of Gas Pulsation Problems." It discusses gas pulsation problems, some of the attempts made to correct them, and gives details on the Fluor Pulsation Dampener.

CHECK THE CARD AT PAGE 248

17—Diesel Engine Cooling Systems

Binks Manufacturing Company, 3114 Carroll Avenue, Chicago 12, has available a 20-page booklet, "Diesel Engine Cooling Systems." Illustrated with pictures, diagrams and blue prints, it shows how water-jacket scale, overheating and breakdowns can be reduced.

CHECK THE CARD AT PAGE 248

18—Boiler Feedwater Controls

Combustion Control Corporation, 77 Broadway, Cambridge 42, Massachusetts, has available Bulletin 104-C, which includes description and installation instructions on its Fireye Boiler Feedwater Controls 15GK1 and 10CB1.

CHECK THE CARD AT PAGE 248

19—Remote Transmission Systems

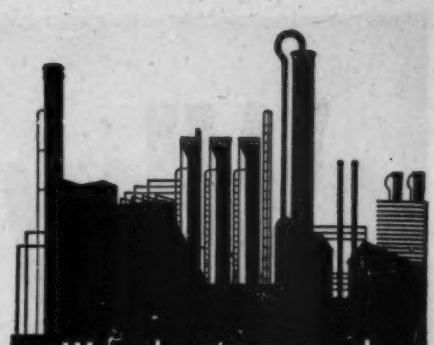
The Brown Instrument Company, Wayne and Roberts Avenue, Philadelphia 44, has available a new catalog, No. 5902, on its "New-Matic" remote transmission systems for applications where electrical transmission for indicating, recording and control of temperature, pressure, flow and liquid level is neither desirable nor permissible.

CHECK THE CARD AT PAGE 248

20—Potentiometers

The Brown Instrument Company, Wayne & Roberts Avenues, Philadelphia 44, has issued Catalog 15-10 on its "ElectroniK Strip Chart Potentiometers" This new development in temperature recording and control instruments is described and illustrated. Electronic "continuous balance" operating principle and resulting advantages of the ElectroniK Strip Chart Potentiometer are featured, as well as constructional details clearly shown in accompanying photographs.

Also included are illustrated descriptions



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SEE PAGE 26

of the various types of potentiometers, standard speed, fast speed and high speed; auxiliary switch forms; the potentiometer controller; precision indicator and thermocouple assemblies. Other useful information can be found in the control forms chart and the list of strip chart and scale ranges.

CHECK THE CARD AT PAGE 248

21—Close-Coupled Vertical Pumps

Peerless Pump Division, Food Machinery Corporation, 301 West Avenue 26, Los Angeles 31, California, has published a 20-page bulletin on close-coupled turbine pumps, describing and illustrating the specialized application of Peerless turbine pumps to installations where short pump settings are encountered and where deep-well turbine pump power and capacity are needed. Details of engineering, construction and operation are described and illustrated.

CHECK THE CARD AT PAGE 248

22—Stock Flanges

Kropp Forge Company, 5301 Roosevelt Road, Chicago 50, has published "Kropp Stock Flange List No. 225," a 16-page bulletin which illustrates and describes forged steel flanges in boiler, marine, welding, high-hub, double-hub, tank, spud, offset and horseshoe types; with sectional drawings, complete specifications and list prices. Also included are tables showing standards for threads, dimensions of wrought pipe, working and bursting pressures of wrought steel pipe.

CHECK THE CARD AT PAGE 248

23—Thermometers and Pressure Gauges

The Brown Instrument Company, Wayne and Roberts Avenue, Philadelphia 44, has issued a new Catalog 6707, on its Rectangular Case Thermometers and Pressure Gauges. Vapo-, gas- and mercury-actuated thermometers and pressure gauges are illustrated and described. Bulbs, charts and interchangeable cases are fully treated, as are the operating features of the instruments.

CHECK THE CARD AT PAGE 248

24—Weld Fittings

Bonney Forge & Tool Works, Allentown, Pennsylvania, has issued a new 20-page catalog which contains complete application information, structural data, installation procedure, temperature-pressure rating charts, specifications and list prices of its "Weldolet" fittings for making branch pipe outlets. It also illustrates and describes drain-out fittings and a complete line of flanges.

CHECK THE CARD AT PAGE 248

25—Furfural

The Quaker Oats Company, Chemicals Department, 141 West Jackson Boulevard, Chicago 4, has released Bulletin No. 204, "Current Uses for Furfural." This 20-page booklet is one of a series being published by the company on furfural and the furans. It discusses the uses of furfural as a selective solvent, a dispersant, resin-former, chemical intermediate, and for other miscellaneous applications.

CHECK THE CARD AT PAGE 248

26—Metal Packing

France Packing Company, 6512 State Road, Philadelphia 35, has issued a new folder describing various types of metal packings. Advantages of packings made to fit standard stuffing boxes are presented.

CHECK THE CARD AT PAGE 248

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SEE PAGE 26

About EQUIPMENT—SERVICE Suppliers

Bertram Manager National Radiator Industrial Division

Appointment of E. A. Bertram as manager of the industrial division of The National Radiator Company, Johnstown, Pennsylvania, was announced recently.

E. A. Bertram

Bertram was formerly in charge of the company's New York industrial sales division. He is a graduate of the University of Illinois and also received an M. S. degree in chemical engineering from California Institute of Technology. He is a member of the American Institute of ChemicalEngineers, the American Society of Mechanical Engineers and the Engineers' Club of New York. Prior to his affiliation with The National Radiator Company, he was associated with The Lummus Company as chief engineer of the heat-exchange division and was general manager of Heat Transfer Products Company.

Rochester Manufacturing Company To Distribute From Dallas

Rochester Manufacturing Company, Rochester, New York, has opened an office in Dallas, Texas, temporarily located at 529½ South Ervay Street. As soon as suitable space can be obtained, a stock of gauges will be carried at Dallas.

D. C. McNall

The office is in charge of Donald C. McNall who has been with the company at Rochester as sales engineer in the LPG gauge division. He will handle liquid-level, pressure and temperature gauges. McNall has been with the company four years, and previously was engaged in distribution of liquefied petroleum gas.

Fischer & Porter Changes Name Of Its Products to "Flowrators"

Fischer & Porter Company, manufacturer of flow-rate instruments, heretofore called "rotameters," will change the trade name of its products to "Flowrators."

The first use of the term "Rotameter" appears to have been made about 40 years ago by an early manufacturer of transparent tapered - tube variable - area flow - rate indicators. It is indicated that this early manufacturer devised a plumb-bob shaped metering element with biased notches milled on the underside of the metering head to impart a rotating motion.

Greatly improved operating stability resulted from use of these rotating elements. Though the name "rotameter" failed to describe either the function of the instrument or any fundamental operating requirement, it has stuck. Fischer & Porter Company has devised the new "bead-guide" metering tube and other methods of float stabilization. The old term thus has lost all significance as applied to the company's products, it was said.

Marc Technical Advisor for C. J. Tagliabue Division

Portable Products Corporation, Pittsburgh, has announced appointment of Henri M. Marc as assistant general manager of the corporation's C. J. Tagliabue Division, Brooklyn. Born in France, Marc served in the United States Army during World War I, and graduated from Carnegie Institute of Technology in chemical engineering in 1922. Thereafter he was associated for a number of years with Mellon Institute of Industrial Research, Pittsburgh, conducting research on asphalt, asbestos and organic felts. He comes to Tagliabue from Philip Carey Manufacturing Company, Cincinnati, with which he had been associated since 1932 as assistant director of research, developing asbestos, mineral-wool and other heat- and sound-insulating products. In addition to his managerial duties, Marc will act as technical adviser for all divisions of the corporation.

Henri M. Marc

Codrington Sales Manager Allis-Chalmers Blowers-Compressors

Charles F. Codrington has been promoted from assistant to sales manager of the blower and compressor department of Allis-Chalmers Manufacturing Company, succeeding A. E. Caudle, resigned. Codrington joined the company as a trainee following graduation from Texas A. & M. College in 1930, and served in the engine and condenser department before joining the blower and compressor department in 1935. His experience includes application of turboblowers to a wide range of industrial and chemical process plants.

Norman W. Stirling Joins Elliott Company at New York

Norman W. Stirling has joined the New York office organization of Elliott Company. Educated at Buchtel College, Annapolis, and the Naval School at Stevens Institute of Technology, Stirling was a lieutenant in the U. S. Navy during World War I at the conclusion of which he and two brothers established their own business as marine maintenance and general contractors specializing on marine engine condensers. In 1927 he joined The M. W. Kellogg Company in charge of sales of

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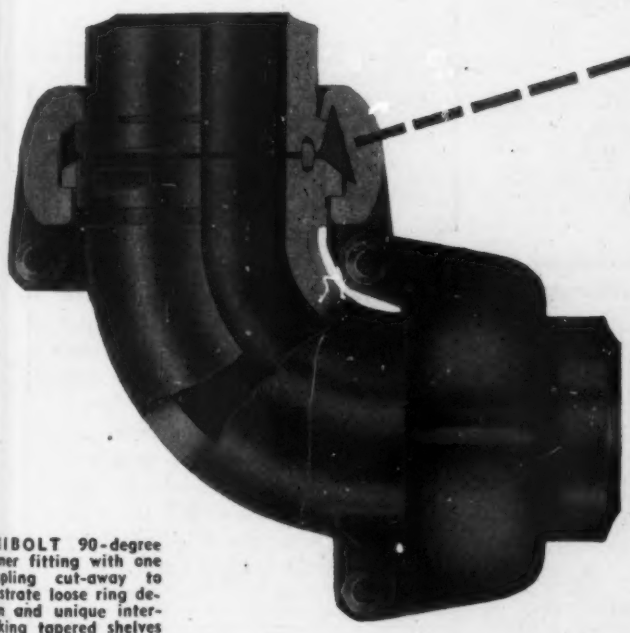

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- Multiplies seat pressure
- Prevents header leaks
- Obviates need for steam in header boxes
- Eliminates tapered plug closures
- Eliminates seal welding
- Permits faster "heading up"
- Permits replacement of a single tube
- Is interchangeable

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Houston, Texas; San Francisco and Los Angeles, California; and
Mayo Building, Tulsa, Oklahoma

THAT "COMPLETE PACKAGE" REFINERY MAY BE OUR ANSWER!

SEE PAGE 26

heat-transfer and petroleum equipment. In 1944 he became manager of sales for Whitlock Manufacturing Company.

As president of the Heat Exchange Institute for a one-year term and as president for three years of the Tubular Exchanger Manufacturers Association, of which he was also one of the organizers, Stirling has been exceptionally active in promoting the mechanical and thermal standardization of tubular heat exchangers for the petroleum industry.

Curtis Pacific Coast Sales Manager for Babcock & Wilcox

Harold P. Curtis has been appointed Pacific Coast sales manager for The Babcock & Wilcox Tube Company, and will maintain headquarters at 634 South Spring Street, Los Angeles.

H. P. Curtis

Before taking this position, Curtis was Pacific Coast sales manager for Rustless Iron & Steel Corporation. Previously he was associated with Columbia Steel Company for eight years, and became manager for that company's stainless-steel sales in Southern California. He also worked with Budd Manufacturing Company on the Pacific Coast and as its sales manager at Philadelphia.

The San Francisco territory and northern California area will continue to be served by Kilsby & Harmon, Inc., as sales representatives of The Babcock & Wilcox Tube Company. In the Los Angeles area, Kilsby & Harmon, who used to represent the tube company exclusively, will act as jobbers for certain seamless and welded specialty tubing products of the company and as mill representatives on certain other products into which their present activities will bring them.

Kemp Manufacturing Company Names Kohut General Manager

The C. M. Kemp Manufacturing Company, Baltimore, has advanced Frank J. Kohut to general manager. He formerly was sales manager and chief of development, and in his new capacity will supervise production, engineering and other internal functions. Kohut is a member of ASME and has been with the company since 1945.

Globe Steel Tubes Promotes Mullen

Globe Steel Tubes Company recently announced appointment of Lee Mullen as general manager of sales. He will have headquarters at the company's main office in Milwaukee, Wisconsin.

Lee Mullen

Mullen has been with Globe Steel Tubes Company since 1943. Previously he was with Sharon Steel Company, Republic Steel Corporation, and Pittsburgh Steel Company.

Eastern Engineering Company Involved in Consolidation

Eastern Engineering Company, New Haven, Connecticut, manufacturers of midget pumps for industrial and laboratory use and of industrial mixing equipment, has been consolidated with Automatic Signal Corporation, East Norwalk, Connecticut, makers of automatic traffic signals and relays.

The new corporation is Eastern Industries, Incorporated. Personnel of both operating divisions will remain substantially the same under the new organization and will continue to manufacture the same products but with greater production, sales and financial facilities.

Graduate Chemical or Mechanical Engineer with experience in gasoline or recycling plant. Give age, experience and educational qualifications in first letter. Address: Box 42-R, c/o Petroleum Refiner, Houston, Texas.

FOR SALE: Complete Propane-Air Plant, 15,000 gallon tank, 200,000 cu. ft. per day natural gas equivalent McKee Diluter, dual stage regulators, Brunner compressor, 60 cycle electrical equipment, valves, fittings, gauges, piping and portable control house. Complete working drawings, instructions, etc. Immediate delivery. Price, $13,500.00 loaded for shipment from Central Pennsylvania. Reply to P. O. Box 413, Hamilton, Ontario, Canada.

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Thoroughly experienced in thermal cracking, skimming, doctor and copper treating. Expert in handling sour crude operation. Highest of references. Available immediately. Address: Box 26-R, c/o Petroleum Refiner, Houston, Texas.

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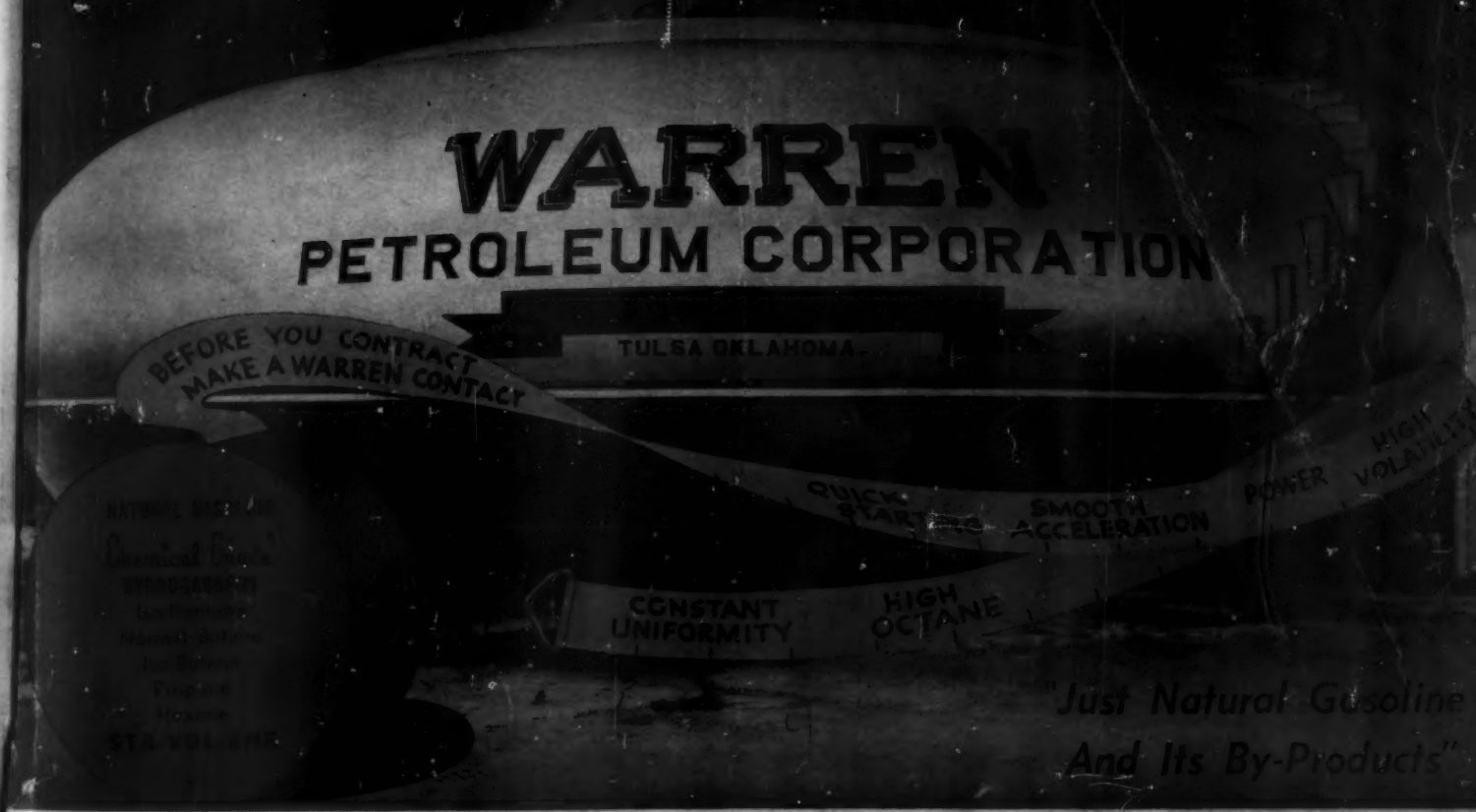

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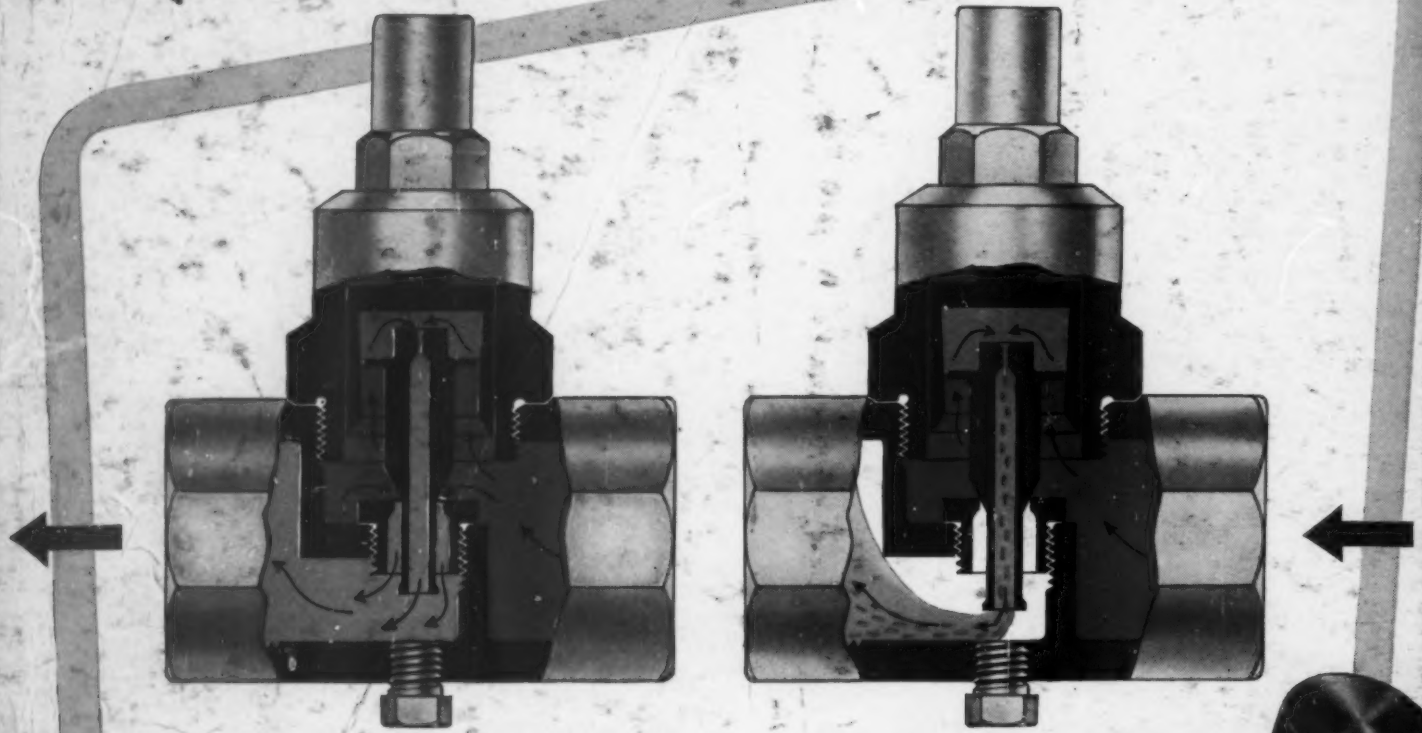
WHY YARWAYS GET EQUIPMENT

Hotter, Sooner



VALVE OPEN—Main flow through seat.

VALVE CLOSED—Main flow shut off.

There's a basic reason why the Yarway Impulse Steam Trap gets equipment hotter, sooner . . . and *keeps it hot.* It's this . . . As soon as steam is turned on, the Yarway trap opens wide and discharges air and condensate continuously until the system is cleared. Equipment is brought to working temperature in the shortest possible time.

Once working temperature is reached, Yarways discharge intermittently to *keep* equipment at peak performance. Under very light condensate loads, discharge is small and continuous through control orifice, and main valve does not lift. *There is no wasteful steam leak,* since a mere 3% of full condensate capacity keeps control orifice completely sealed against discharge of live steam.

No wonder more than 450,000 Yarways have already been sold. They not only speed production . . . but also produce substantial operating economies.

Other Yarway advantages—*small size, easy maintenance, low price.* For full description and operating details of the Yarway Impulse Steam Trap write for Bulletin T-1739.

Try some Yarways today. See your nearby Mill Supply Dealer.

YARNALL-WARING COMPANY, 128 Mermaid Ave., Phila. 18, Pa.

Yarway Impulse Steam Traps are now made and sold in Canada and Great Britain

YARWAY IMPULSE STEAM TRAP

Precision

IN BIG THINGS TOO

Stainless steel bubble trays and caps being installed in *stainless* clad fractionating tower.

These ARE THE VALVES THAT HAVE CONQUERED THE PRESSURE LOADING PROBLEM

AVAILABLE IN 2", 2½" AND 3" SIZES

Plate 945
Straight Type McDonald Slo-Self Closing Loading Line Valve.

Plate 967 Adjustable Handle
Supplied when it is desired to have handle in special position when either opened or closed.

Plate 956
Angle Type McDonald Slo-Self Closing Loading Line Valve.

Smooth "Cushion Closing" Ends Shock and Hammer —Prevents Costly Damage to Line Equipment

When the valves of a pressure loading line close with a "bang" there can be but one result—shock, hammer, damage, expense . . . McDonald Slo-Self Closing Loading Line Valves *can't* close with a "bang" because when the valve plunger moves toward the closing position liquid is drawn into the control chamber, assuring hydraulic control and smooth, shock-free closing . . . Years of performance have established this patented valve as the practical and positive solution to the most serious problem associated with pressure loading . . . An irresistible investment because it protects and conserves all of the costly units that make up a modern line . . . Write for further details.

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VACUUM BREAKER
Permits automatic and instant draining of fill pipes when loading line is closed. Brass screens give fire protection and prevent entrance of foreign matter into valve.
McDONALD
DUBUQUE
Plate 988—Size ⅜"

McDONALD
SLO-SELF CLOSING LOADING LINE VALVES